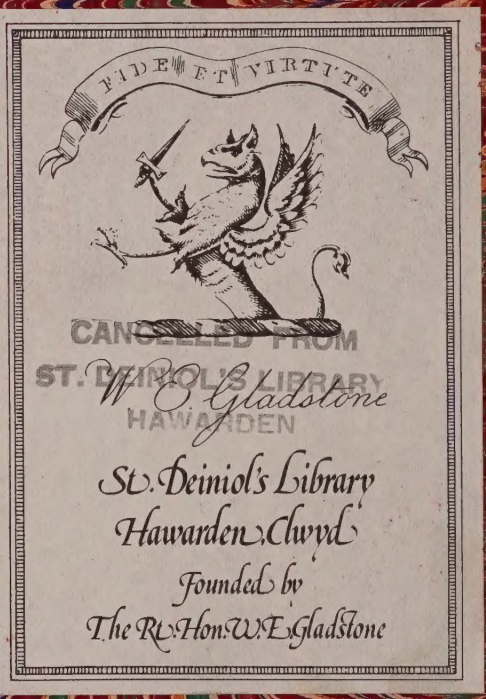
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KAISER FRANZ-JOSEPH'S FJORD AND PETERMANN'S PEAK, EAST GREENLAND.

(AFTER A PICTURE BY ZIMMERMANN).

OUR EARTH AND ITS STORY:

A Popular Treatise on Physical Geography.

EDITED BY

ROBERT BROWN, PH.D., F.L.S.,

AUTHOR OF "THE PEOPLES OF THE WORLD," "THE COUNTRIES OF THE WORLD," ETC. ETC.

* *

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Fig. 1.—THE ATOLL OF WHITSUNDAY ISLAND.

OUR EARTH AND ITS STORY.

CHAPTER I.

ROCK WASTING AND ROCK MAKING.

Summary of the Conclusions derived from a Study of the Geological Action of the Elements—The World always Making—Its Materials constantly Reassorted—What is Lost at one Place is Gained at Another—Conservative and Reproductive Actions alternate with Erosive or Destructive Ones—The Cataclysmic and Uniformitarian Schools not necessarily Antagonistic—Rock makers which are not Rock wasters—Deep-Sea Oozes—Plants—Floating Islands—Earth Worms—Exaggerated Views regarding their Importance—Soil often due to Mould carried in the shape of Dust by the Wind—The Loss—Ants—Coral Reefs—Their Different Shapes—Fringing and Barrier Reefs—Atolls—Theories of their Origin—Darwin's View—The Later Explanations of Semper, Murray, Guppy, and others—The Peopling of Coral Reefs, etc.

THE reader who has followed the descriptions in the first volume of this work will have seen that the air and the water are constantly warring against the land. No sooner is a rock brought within the influence of these erosive agents than it is attacked by the sea, on the bottom of which it was originally formed, or by the rivers, which wore out of some pre-existing land the materials of which it is composed; by water in the form of ice, or by damp winds, in which, again, moisture plays the principal part. In this way, the surface of the pristine block of land is carved, as if by the hand of a sculptor, into hill and dale, plain and plateau.

But this action of the elements must have been going on ever since the World assumed anything like its present shape. Long before the later sedimentary beds were laid down in the ancient seas or lakes, rivers and breakers, glaciers, and other erosive agents, must have been at work, since these strata are due to such wearing away either of pre-existing beds, or of the igneous rocks on which all of them rest, and which, therefore, must have been the primeval material out of which first bedded rocks were formed. It is, however, a vain endeavour to trace the original contour of the mass, the hills in which the first rivers arose, or the valleys through which

they coursed. Again and again, in the evolution of the World, nearly every inch of what is now dry land has been under water, and in some instances the same section has been elevated and submerged many times in succession, though with vast intervals of time between them. There are even cases in which distinct evidence is forthcoming of the rocks in a cutting presenting an alternation of fresh-water and marine beds.

This elevation and depression are, we have seen, still in progress. Regions have risen above the sea in comparatively recent—even within historical—times, while others have equally recently presented proof of a gradual sinking (Vol. I., pp. 168–177). This is more frequent than sudden rise and fall, though even these phenomena, which have played so prominent a part in the past, are not absent from the times in which we live (Vol. I., pp. 163–167, 247–250). Modern rivers are forming by the sediment which they deposit in lakes and seas, deltas comparable with the sedimentary beds of former eras, and the ocean and other denuding forces are wearing away existing continents at such a rate that, given time—and the geologist reckons by millions of years, while the historian is pleased if he can but recount the story of thousands,—they are quite capable of depositing the materials of new ones in the waters, into which the result of their unceasing labour is tossed (Vol. I., pp. 312–318). The volcanoes of our day are upheaving, from the bowels of the old globe, the lava and ash of its still mysterious interior in much the same manner, and in much the same degree, as in times the distance of which it is impossible to reckon with any approach to accuracy (Vol. I., pp. 155–168); and it is more than likely that, though the cooling of the primeval globe has now gone so far that its wrinkling is no longer sufficient to elevate any range, in the earthquakes with which we are familiar much the same process is going on, though on a smaller scale. It is, however, certain that water in various shapes attacks the newly-accumulated volcanic cone, or lava flood, and if it is permitted to have its own way will soon cut it into valleys, or by leaving fragments of it standing while the less stubborn ashes and the like materials are swept away, form hills of circum-denudation, alongside those of accumulation and upheaval (Vol. I., pp. 126, 127). Deserts are, in like manner, still forming, many tracts which were at one time fertile soil, or plains underlaid by hard rock, being now wastes of drifting sand (Vol. I., pp. 8, 328). Prairies are forming in the beds of drained lakes, and lakes are being transformed into valleys, owing to the rivers which empty them wearing their beds deeper and deeper until they are on a level with the bottom of the lake (Vol. I., pp. 326, 332). Finally, there is every reason for believing that either during earthquakes or during volcanic eruptions, faults of exactly the same character as those already described (Vol. I., pp. 80, 81) are formed in the oft-times dislocated strata affected by these commotions (Vol. I., pp. 246, 252, 274, etc.).* There is, therefore (Vol. I., p. 72), nothing which leads to the belief that the ways of the old world were different from those of the new one, or that in the remote ages, in spite of regions now Arctic being semi-tropical, in spite of plants and animals being widely different, in spite of the distribution of land and water being different, the broad laws governing it were in any important respect different from those at present in force. In brief, the

* In America some of the greatest faults are of comparatively recent geological age. In Europe faults, as we have already indicated, so rarely, if ever, give rise to any topographical feature, that their existence would commonly not be suspected. In the Great Basin of the Western United States, this rule is conspicuously violated over an area about as large as England. In this region, as well as in others of similar construction farther south, the faults break through all formations including the recent; and the upheaved masses stand up bordered by abrupt cliffs, that have not retreated perceptibly from the line of fracture. The depressions among the tilted blocks are occupied by numerous lakes, which are thus, in respect to origin, almost as novel as the forms of the faults themselves, though we have already indicated the existence of this extremely rare form of water accumulation (Vol. I., p. 325). The American geologists are even beginning to revert, owing to what is seen in the local upheavals of the Henry Mountains in the Colorado Plateau, to the doctrine of craters of elevation now (Vol. I., p. 183) almost abandoned in Europe. (*Science*, Vol. VI., No. 128, pp. 41, 42.)

means by which the stratified rocks were laid down are still in operation laying down others, which will in time be elevated and form strata and formations, with their included fossils, in the shape of the remains of plants and animals which have become embedded in them (Vol. I., p. 72).

The World is still making; it is still unfinished. The circulation of matter is always in progress. Nothing is lost; nothing is gained. For if the rivers or the sea, the winds or the glaciers, take away material from one spot, they deposit it at another. The position is changed; the shape into which the shifted matter is worked up is different; but the aggregate of the World's substance is much the same as ever it was. In walking along a road, for example, we pass a quarry out of which great quantities of stone have been dug. But by-and-by we come to a town, a village, or a row of houses, which have been built out of the rock. In this case the denuding agents have been the quarry-men, and the reconstructing ones the masons. Yet the surface of the earth a few miles away has gained what its crust at a depth of a few hundred feet has lost. It is so with all the natural erosive agents. They wear away, but they also build up. They are wasters of what their predecessors laid down; but they are at the same time rock destroyers and rock makers.

It is these among other reasons which lead the modern school of geology to reject the invocation of "Cataclysms" and "Catastrophes" different in kind or even in degree from those which have been always at work, and to accept the slow, steady action of the forces described in our first volume as the causes to which we must look for an explanation of the history of the World, during the period when the beds composing its crust were formed or the dykes of igneous rock permeating them discharged. However, when the geologist talks of "Uniformitarianism" (Vol. I., p. 118) he does not—as some recent opponents of the doctrine seem to imagine—mean the action of agencies necessarily insignificant in themselves, and powerful owing only to their long operation.* All he claims is that no novel forces have been called into play: the old ones, be they violent or gentle, are as yet, as they always have been, at work. The forces now in action are mild, but they are ofttimes varied by others which are catastrophic. The Mississippi, or the Nile, rolls its mud-laden flood seaward, the glacier grinds through a valley with its load of moraine, the geyser heaps up its deposits of sinter, and the decaying vegetation of the swamp slowly prepares the materials which are to be the coal of the far-distant future. But while this important work in world-building is silently in progress, Krakatau explodes with terrific violence, or Lima, or Lisbon, is levelled by earthquakes which remind us that uniformity is not monotony. In the past, therefore, as in the present, the history of creation was no more one continual "catastrophe" or "cataclysm," than the chronicles of Nature are at present unbroken by events which deserve that much-abused title. But they are not the less uniform. Professor Huxley† has, indeed, pointed this error out in much the same way when he suggests that catastrophes may be "part and parcel of Uniformity." The working of a clock is a model of uniform action, but the striking of a clock is essentially a catastrophe. "The hammer might be made to blow up a barrel of gunpowder or turn on a deluge of water, and by proper arrangement the clock, instead of marking the hours, might strike at all sorts of irregular intervals, never twice

* Mr. Howorth, for instance, in an elaborate work intended to "confront the theory of uniformity with the facts of geology," cites the Colorado cañons, the Lisbon earthquake, the Biesbosch breaking-in of the Lower Rhine, the formation of the Zuider-Zee, the inroads of the German Ocean on the Dutch coast, the disappearance of islets on the south-western coast of Iceland, the "sudden creation and rapid disappearance of the submarine islet near Santorin," and the upheaval of a large portion of the coast of Chili as "elementary facts which strain the theory of uniformity to the breaking-point." All of these cases we have discussed in our first volume. It would scarcely be possible to select instances more fully confirmatory of what this writer attempts to confute.

† "Presidential Address to the Geological Society," 1869.

alike in the intervals, force, or number of its blows. Nevertheless all these irregular and apparently lawless catastrophes would be the result of an absolutely Uniformitarian action, and we might have two schools of clock theorists, one studying the hammer and the other the pendulum."

Much of this we have already said in another way; but, as it lies at the bottom of all geological—in truth, of all biological—teaching worthy of the name, the reader cannot be too often or too thoroughly reminded of those fundamental doctrines, which we are entitled to regard as facts.

Rock Makers.

In this way all the denuding agents are rock makers as well as rock wasters, for they destroy one rock only to reconstruct another out of the materials worn from it. The "Clastic beds" are entirely of this character (Vol. I., pp. 51–54). But we have seen that some rocks are of chemical origin (Vol. I., pp. 66–71), while others, like coal (Vol. I., pp. 54–66), are of organic origin. The materials which make up these beds may therefore be regarded as exceptions to the maxim that the makers of strata must first be the destroyers of previously existing rocks. In reality, they do not altogether depart from this broad law, for the substances in question are only transformations of something which existed in another form. The so-called chemical rocks are only the consolidated materials derived from land and water; while even plants and animals, the bodies of which constitute the substance of thick strata, are, in truth, merely the elements of which they robbed the earth, the air, and the water, reassorted into the components of bone and muscle and fibre. Yet here we approach to actual rock makers which are not, except in an argumentative sense, rock wasters.

Deep-Sea Oozes.—The Deep-Sea ooze is in a still broader sense (Vol. I., pp. 35, 74) a rock maker without being a rock destroyer, for the slender shells which constitute its legacy to Time are formed of the lime which the tiny foraminifera composing it extract from the waters of the ocean. The *Globigerina ooze* (Fig. 12, Vol. I., p. 36) contains from 40 to 95 per cent. of the dead shells of such foraminifers as *Globigerina, Orbulina, Textularia, Pulvinulina,* etc., mixed with the silicious frustules or cases of the minute plants known as diatoms (Vol. I., p. 353), and the skeletons of radiolarians—minute animals in which the slimy "scarcode" body is enclosed in a more or less membranous or "chitinous" capsule, or surrounds a skeleton of spicular or radiating spines or chambered shells, which are usually silicious,* never calcareous. The students of the Deep-Sea dredgings made by the *Challenger, Porcupine, Blake, Tuscarora,* and other ships, also distinguish a *Diatom ooze* as forming on the sea bottom, consisting, for the most part, of the frustules of diatoms (Vol. I., p. 353). The "Kieselguhr" and the "Tripoli" (Vol. I., p. 55) were in all likelihood formed in the same way (Vol. I., pp. 352, 353; Figs. 182, 183), though the latter are essentially freshwater and not marine formations. The *Pteropod ooze* is on the other hand, to a large extent made up of globigerina and other foraminiferous shells, but with this difference, that mingled among it are the shells of the floating molluscs, which—like *Cleodora* and *Carinaria* — swim on the surface of the open ocean often in vast numbers. Finally, Murray and Renard distinguished a *Radiolarian ooze,* mainly composed of the skeletons of the tiny organisms which give it the name they have applied to it, mingled with the red clay which is everywhere so characteristic of the deepest sea bottoms (Vol. I., p. 35) all the world over.

In other words, there is forming in the abysses of the ocean a deposit due to the shells of minute animals and the cases of minute plants which have fallen to the bottom after the death of their inmates, this ooze consisting of one or other of the constituents mentioned, just as Foraminifers, Diatoms, Pteropods, or Radiolarians happen to be most abundant in the water

* Nicholson: "Manual of Zoology" (1887), p. 89.

overhead.* In freshwater lakes and ponds the marl formed by the shells and other exuviæ of fresh-water mollusca may, in some respects, be regarded as analogous to the Deep-Sea deposits, being formed in much the same manner (Vol. I., p. 52). As a rule, however, unless when the broken shells form a "sand," as at many places on the English (Vol. I., p. 350) and other shores, the action of boring shells is more destructive than formative of rocks. The *Pholas* and *Saxicava*, for example, among mollusca, and various sea-urchins, sponges, and worms, among other families, bore into rocks, etc. (Vol. I., Fig. 88, p. 172), and so allow the sea to gain an inlet, and thus more speedily than could otherwise be the case effect their ruin.

Influence of Plants.—In the same manner, plants will often aid in the destruction of soil and even of rocks. In a forest, or indeed in any situation, the roots in their search for food enter into the crevices of the underlying rocks which have not yet been disintegrated, and as they increase in size rive them asunder. This goes on until not only is the layer into which the main roots have penetrated broken up, but, the fibrillæ of the roots and rootlets acting in a similar manner, the hard mass is in time reduced to bits so small that they seem as if acted upon by a hammer (Fig. 2). Then as the deep layer of decaying vegetation—fallen leaves and twigs, and the withered remains of non-perennial plants — accumulates on the surface, the carbonic acid gas (formed by the union of the carbon of the vegetation with the oxygen of the air dissolved in rain-water) begins to aid the mechanical action described, by its chemical influence on the rock, provided it is a calcareous one. Thus vegetable mould is formed (Vol. I., p. 66). In New Zealand, it has been found that the introduced thistles, which do so much damage by spreading over cultivated land, are not altogether without their merits. For it is now known that in time the thickets of thistles exhaust themselves and die down, leaving the ground permeated in all directions by their long roots, and thus admirably fitted, when they decay, for the penetration of water which, in stiff unbroken soils, works down with difficulty.

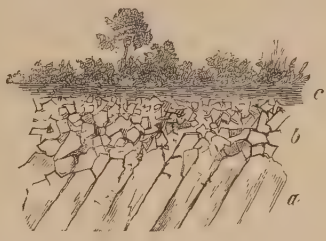


Fig. 2.—FORMATION OF SOIL BY THE AID OF TREE ROOTS.

a, Beds of rock tilted on end; *b*, The same broken up by the penetration of tree and other roots; *c*, Mould formed by this material disintegrated by the weather and by mixture with decayed vegetation.

Plants also play the part of conservative agents by protecting the rocks beneath from the action of the elements. This is strikingly seen when a glaciated surface, which in course of ages has been concealed by vegetable mould, is uncovered. The grooves and polishing are often as fresh as if they had been made a year or two before, while on the neighbouring surface, originally subjected to the same action, but from which the rain has washed the protecting soil, the marks of the old glacier are getting effaced. In like manner, when a long-buried piece of sculpture is dug out of earth not likely to act chemically upon it, the clearness of the carving and the legibility of the inscriptions compare favourably with the crumbling aspect of a similar work of art which has been subjected to the erosive action of the atmosphere for only a year or two. Forests also, as every one knows,

* "Report of the Scientific Results of the Exploring Voyage of H.M.S. *Challenger*—Narrative," Vol. I., pp. 916–926, Plate N; Murray, *Proceedings of the Royal Society*, Vol. XXIV., pp. 471–537; Murray and Renard, *Proceedings of the Royal Society of Edinburgh*, Vol. XII., pp. 495–529; *Scottish Geographical Magazine*, 1887, pp. 553–561; Report on the Deep-Sea Deposits in the "*Challenger* Reports"; "Den Norske Nordhavs Expedition, 1876–78"; Hoyle, *Scottish Geographical Magazine*, 1887, pp. 472–478, 561–567; "Die Ergebnisse der Untersuchungsfahrten S. M. Knbt *Drache* in der Nordsee in den Sommern 1881, 1882, u. 1884"; and Mill, *Scottish Geographical Magazine*, 1887, pp. 385–398.

protect the soil from disintegration by breaking the heavy tropical showers and binding the ground into a matted mass, against which the "spates" have comparatively little influence (Vol. I., p. 278). On sandy sea-shores the bent grass (*Ammophila arenaria*) and the various species of *Carex*, particularly the "sea bents" (*Carex arenaria*), act in the same manner, and in the Tropics the mangrove thickets, which line low-lying, swampy shores, not only prevent the soil from being carried away by streams and tides, but by entangling the floating vegetation and then the mud succeed in gradually reclaiming and adding to the land.

Floating Islands.—In many tropical countries the torrents of rain or the sudden floods often sweep away part of a river bank with the matted carpet of vegetation, and carry the latter in its currents till it is set adrift in the lake or sea into which the river empties. Mr. Forbes expresses amazement at the deep ravines which the rains of only one season excavate in the Sumatran slopes, and at the vast amount of material which even in a country covered with vegetation has been washed away. When a river is flooded after a few hours' rain, not only are fruits, branches, and large trees brought down, but on one occasion a broad slice of land, with the bamboos growing on it, was swept into the torrent.* If the vegetation is carried into the sea it must, of course, die; but if a lake is its ultimate goal, it may float about in an inextricable tangle, its roots drawing nutriment from the water, and forming soil by the decay of its leaves, mingled with the earthy matter which has not dropped through the sieve. In this way many of the great American and other rivers are dotted with islands composed of little more than matted plants, half rooted in the mud, but daily adding to their mass by filtering the muddy stream, and storing away among its decaying leaves the silt which it forces the flood to leave behind. In the Lake of Nicaragua there are several floating islands of this tangled tropical vegetation, which drift about on the surface, hither and thither before the wind. When crossing that Central American lake, in the year 1866, the floating islands seemed to run a race with our boat, the wind catching them as if they were on sails, and carrying these green masses in any direction according as the breeze happened to blow. The famous floating island of Derwentwater or Keswick Lake, in Cumberland (England), is another illustration, not so much of what these paragraphs are concerned in describing, as of the formation of carbonic acid and other gases under peculiar circumstances, and of their disrupting effects on the earth. In reality, the "floating island" does not float at all, in the usual sense of the term. Unlike the vast masses of detached tropical vegetation which so often impede the great American rivers, and may be seen drifting before the wind on the Lake of Nicaragua, the Derwentwater island never changes its position, being always in the south-eastern corner of the lake, opposite Lodore Falls, and about 150 yards from the land, in a place where the depth of the water does not on an average exceed six feet. It generally rises after an interval of about two to five years—sometimes longer, sometimes shorter, though the ascension usually takes place after a long spell of dry, warm weather. These conditions prevailed during the summer of 1887, when the island, after having been at the bottom for three years, rose to the surface in the month of July. Its figure and dimensions are variable. Sometimes it contains half an acre of land, at other times the area of the island is reduced to a few perches, though, as it extends in a gradual slope under water, a much greater portion of it is raised from the bottom than appears on the surface. But it never entirely detaches itself from solid earth, and rarely rises far above the level of the lake. Once, however, having reached the surface, it fluctuates with the rise and fall of the water, after which it gradually sinks to the bottom. When at rest in this position it appears

* Forbes: "A Naturalist's Wanderings in the Eastern Archipelago" (1885), pp. 174, 184.

covered with the ordinary water-plants common to Derwent and the other lakes of the neighbouring regions, though after a brief stay above water the colour and density of the verdure are much improved. The island is composed for a few inches of its depth of clayey soil, in which the tangled mass of vegetation has fixed its roots, binding the whole together in a matted turf, and the rest of its substance is composed of decayed plants, forming a layer of loose peat about six feet in thickness, the whole resting on the clay bottom of the lake. What force raises the island to the surface has been often discussed. Endless theories on the subject have been promulgated. But it is now very generally believed that the motive power is the gases generated by the decay of the plants which make up the greater part of the island. These gases discharge themselves through the cracks made in the mass when it is raised to the surface, and may be further dislodged by probing the body of the island with a pole. From an analysis by Dalton, it was found that the air was a mixture of nitrogen, carburetted hydrogen (coal gas), and a little carbonic acid. The accumulation of the gas buoys up the island until it is raised to the surface. Then, after the gas is either entirely dissipated or absorbed by the water, the island slowly returns to the bottom, where it remains until the accumulation is again sufficient to render it lighter than the water. There is no instance on record of the island rising during the winter season—from June to October being the time when the phenomenon takes place. This fact is quite in accordance with the explanation vouchsafed, since during the warm months the generation of gas is more rapid than at any other period of the year, while the depth of the lake being less, the labouring island has a lighter superincumbent weight to overcome.

Earth-worms and the Löss.—The influence of earth-worms has already been alluded to (Vol. I., p. 66) as one of the agencies at work in keeping matter in circulation. The researches of Charles Darwin have been the means, not only of calling attention to this subject, but of greatly adding to the knowledge of which he first put us into possession. Earth-worms, it is known, are very widely scattered, though it is difficult to understand how creatures so intolerant of salt water could have reached islands which there is no reason for believing were ever connected with any continent—Kerguelen Land, for example—unless by the intervention of man or the currents carrying them in soil around roots, or in other conceivable ways. Man, indeed, seems strangely connected with the spread of these creatures. It is known that in Manitoba and the Canadian North-West Territories, and over the prairie lands of Kansas, the Indian Territory, Idaho, and Washington Territory, there is an entire absence of earth-worms, though they are abundant in Ontario and in other long-settled parts of America. Cold penetrating to a depth greater than that usually frequented by the worms, or prairie fires sweeping the surface, have been volunteered as possible explanations of their absence in the vast areas in question. It is, however, well known that when virgin soil is first broken up no worms are seen, and this fact holds true whether the ground has been swept by fires, or is woodland on which for unnumbered ages forest trees have grown. Indeed, until a place has been inhabited for about five years, it is the opinion of the frontier settlers in Canada that there is no chance of seeing earth-worms. At first, they are found about the stable-yard, then in portions of ground enriched by stable manure, till they are at length found in all soils, either those cultivated or those manured by stable litter. In Iceland they are found only in the vicinity of the scattered farm-houses, and even in the long-cultivated districts of Midlothian, in Scotland, they are much more plentiful near dwellings than elsewhere.

It is, therefore, somewhat premature to attribute any very important geological function to earth-worms, since that function must, if the statement made on the authority of various

Fig. 3.—THE LÖSS COUNTRY NORTH OF TAI-YUEN, IN THE PROVINCE OF SHAN-SE, CHINA, ERODED INTO VALLEYS AND CASTLE-FORMED ROCKS. *(After Ferdinand v. Richthofen.)*

authoritative writers regarding their absence from virgin soil is to be accepted as accurate, be entirely confined to lands which have come under the influence of agriculture.

The Löss.—The fine dark powdery soil of Manitoba, like the Black Earth or "Tschornosjom" of Russia (p. 66), is not improbably vegetable mould which has been carried over the plains in the form of dust. This is the case in many other regions. Over nearly one half of Asia this blown dust forms a deposit in some places—in the provinces of Honan and Shan-se in China—between 1,600 and 1,700 feet thick; and in Khotan, where the sun is sometimes obscured by clouds of it, the inhabitants regard it as a manure of the utmost importance.* This fine dust is carried by currents of air from the desert and deposited on the plains, even when there is no wind blowing. M. d'Aoust has found argillaceous deposits on the flanks of the loftiest mountains in Mexico, which could not be attributed to the decomposition of rocks *in situ*, or to alluvium brought by rivers or by the rain, but only to atmospheric currents. Day and night the winds raised the particles from the plains until the deposits on the hills had reached a thickness of from 100 to 130 feet, and in places to nearly 330 feet. The upper part, which is generally finer, stops at the limit of herbaceous vegetation, beyond that elevation there being nothing to retain the dust, which in consequence is swept away by the wind, the rain, or the melting snow. In Tibet, Prejevalsky met with analogous aërial deposits which are being formed under the influence of the powerful winds which prevail on the high plateaux of Central Asia.† In China, according to Richthofen, the dust is cut into valleys and ravines, and excavated into chambers for the shelter of the dense population of the district which it fertilises (Fig. 3).‡ The ruins of old Nineveh are in places overlaid with the dust to the depth of twenty feet or more, and as vegetable mould has covered it, the layer beneath is not only protected, but increases in thickness. This "eluvium" or "æolian (*i.e.* wind-made) formation"—which is neither stratified, in the strict sense of the term, nor unstratified, in the manner which we understand by that word when igneous rocks are spoken of—was first observed in the valley of the Rhine, when it obtained the name of "Löss," and is distinguished by the presence of various fantastically-shaped concretions due to the consolidation of the clay by a limy or ferruginous cement through infiltrating water, and known as Lössmännchen, Lösspuppen, or Lösskindeln (Fig. 4). Among the Carpathians it is found at great elevations (up to over 5,000 feet), though in China it attains a still greater height—namely, upwards of 8,000 feet in Shan-se, and in other parts an even greater altitude.

Fig. 4.—THE CALCAREOUS CONCRETIONS OF THE RHINELAND LÖSS, THE SO-CALLED LÖSSMÄNNCHEN, ETC.

At one time the Löss was generally attributed to glacier streams, and possibly it may be in places mingled with the mud which the infra-glacial river deposits. But while land shells (Fig. 5) are extremely common, mingled with the bones of land animals, fresh-water species are rare, and marine are unknown. This last fact puts out of the field the theory which ascribes the löss to the sea, while the great height which the "mountain löss" attains, its independence of the contour of the

* Johnson, *Journal of the Royal Geographical Society*, Vol. XXXVII., pp. 6, 7; Ruprecht: Ueber den Ursprung des Tschornosjom oder des Schwarzbordens (1864), etc.

† *Proceedings of the Royal Geographical Society*, 1885, p. 614.

‡ "China," Vol. I., p. 97.

country, and the nature of the animal remains found embedded in it, make it in the highest degree improbable that it is due to the operation of rivers, either in the shape of floods or

Fig. 5.—SHELLS FOUND IN THE RHINELAND VALLEY LÖSS.

1, Succinea oblonga; 2, Pupa muscorum; 3, Helix hispida.

dammed up into lakes. If, therefore, this deposit is not to be traced to exceptional causes, it may be found in strata of any age, though the löss so called is classed among the most recent formations. At the same time, it is only just to say that many geologists of eminence do not agree with Richthofen's conclusions, and attribute the European löss, at all events, to fluvio-glacial agencies, and it is not unlikely that some of the Rhineland deposits are to be ascribed to causes very different from those of China.

Earth-worms.—This shows that we must be cautious in accepting the sweeping deductions as to the action of earth-worms in forming—or rather in bringing to the surface—soil, which were in vogue immediately after the publication of Mr. Darwin's researches.* That illustrious naturalist, indeed, while acknowledging the part performed by dust in dry countries where for months no rain falls, denied the importance of this agent in countries where the summer is not long and dry, and in "humid vegetation-covered regions like Great Britain or Continental Europe." Yet it is not uncommon, Mr. Clement Reid tells us, for the whole of the finer soil in the Lincolnshire wolds and on the Norfolk coast, with the sown seed, to be blown away by the equinoctial gales. This happened a few years ago at Cromer, three times in succession in one spring, until finally the field was left fallow, "as the whole of the soil was banked like a snowdrift against the hedge." Moreover, though the soil is, as a rule, formed by the distintegration of the underlying rock, it very frequently contains foreign substances, which must have been blown from a distance, not unlikely at a time when the space now occupied by the North Sea was an extension of the Continental plain, and the fierce East winds brought their burden of March dust from regions whose surface had been disintegrated by the frosts of winter.

This, however, is an interlude and a caution not to be too positive. Yet, unquestionably, earth-worms exert a very appreciable geological influence, and therefore deserve a permanent place in the story of how the world has been made, or is making. They penetrate to the depth of five feet or more, and are constantly bringing up from that depth fresh soil of a finely-levigated character, so that what is removed by the rain or blown to a distance by the wind is in this manner being renewed by their agency. Worms thus to some extent, though in a rather more expeditious manner, act very much as plants do; for the roots of trees and other vegetables, whose food-seekers stretch far into the ground, find nourishment in the dead matter of which the soil is composed, and then, in the laboratory of their cells, transform it into tissues, which, when they decay, or when the leaves which are formed of them fall, restore to the surface of the earth a large portion of the material thus transferred from the depths below. The worms, however, while they do not metamorphose an inorganic into an organic substance by passing the soil through their bodies, levigate it into that comminuted condition seen in their castings. Humic acid being generated in the intestines of these creatures, the stones and other rock particles out of reach of ordinary erosive agents are acted upon, while the little pebbles or chips of stone which are swallowed by the worms only leave their gizzards after being more or less completely triturated. The worms also, being entirely vegetable-feeders — for they swallow inorganic matter merely for the purpose of benefiting by the organic material scattered throughout it—rapidly transfer to the layer of mould on the surface the residuum of their meals.

* "The Formation of Vegetable Mould through the Action of Earth-worms" (1881).

In this way—at least so far as the formation and fertilising of the British soil is concerned—the earth-worm is a more important functionary than the wind, though, as we have seen, it may not unfrequently furnish the material on which the breezes act. Darwin has calculated that in many parts of England "a weight of more than ten tons of dry earth passes through their bodies and is brought to the surface on each acre of land; so that the whole superficial bed of vegetable mould passes through their bodies in the course of a very few years." Professor Hensen * has calculated that 53,767 earth-worms are to be found in every acre of garden ground, and about half that number in ordinary pasture land, while other observers have ventured on even higher estimates, certain rich alluvial soil in New Zealand having, on an average, eight earth-worms per square foot, so that there must be a total of nearly 349,000 per acre. The New Zealand earth-worms, however, not only burrow in the earth, but during the night climb trees in search of food, so that they also aid in forming mould by bringing the material from above as well as from below. But, of course, as the worms support themselves on the material thus gathered, all of it does not return to the soil. Worms, also, are extensively devoured by birds, frogs, toads, and fish, and may often be seen hurrying out of their burrows and across the garden walks to escape moles and the carnivorous larvæ of certain beetles; though, of course, as in the end these worm devourers die and crumble into dust, the globe does not lose or gain much by their growth and decay. Worms, however, do more than this. The common earth-worm (*Lumbricus communis*) does not, perhaps, add much to the quantity of soil, since it works chiefly in the vegetable mould. But, as both Müller and Hensen have shown, a larger species (*L. terrestris*)† burrows deep in the subsoil, and only comes to the surface on mild, rainy nights. It therefore not only adds to the surface mould, but by enabling rain and the carbonic acid of the air to gain access to the underlying clay, chalk, and other rock, assists indirectly in erosion, and consequently in fertilisation.

Ants.—Every burrowing animal must in a greater or lesser degree reassort the soil, and expose it more fully to the action of the denuding agents. But the influence of the mole, or the fox, or the rabbit, or the prairie dog, or the viscacha, is in this respect so trifling that it is scarcely worth taking into account; though unquestionably, when the burrow is close to the sea-shore, or is within the area of a sudden flood, by giving admittance to the waves or the current, it will help in the work of waste.‡ Ants in certain countries, by attacking any timber and speedily reducing it to dust, have also a claim to be regarded as geological agents; and in Central Africa, where the white ant tunnels the ground in all directions and throws out earthworks and hillocks, their work in the rearrangement of the materials of the upper layer of the Earth's crust is important enough to deserve notice. These hillocks are often five or six feet high, and during the dry season are consolidated into a material scarcely less durable than stone (Fig. 6). But, under the influence of the dense tropical rains, the hills disappear and, according to Mr. Henry Drummond, are washed down into the valleys, where they add to the amount of alluvial soil, or into the rivers, to be ultimately deposited in their deltas or on their overflow-ground, miles and miles away from the spot where the industrious Termites had reared their many-chambered dwellings. Even in England, ant-hills, by exposing the otherwise protected under-soil to the influence of the

* *Landw. Jahrbuch*, Vol. XI., p. 661.

† The giant *Lumbricus microchæta* of Cape Colony is often in its unrelaxed condition more than six feet long.

‡ Heligoland (Vol. I., Fig. 9) is often described as an island which has been greatly decreased in size by the sea, aided by the burrowing of rabbits. This could, no doubt, have happened, though, at the same time, it is reasonable to suppose that animals so mischievous would not have been long permitted on such a little spot. However, as a matter of fact, there are not any rabbits on the rock island, and the few on the sand island—recent introductions for sporting purposes—are, from a geological point of view, quite ineffective.

weather, play their part in the story of the world. Ants and earth-worms — the latter rarely, if ever, found in boggy soils, peat mosses, and heather-clad hills *—however, do not, as might be expected from the stinging propensities of the former, frequent the same ground. Mr. Kinahan is, indeed, inclined to think that, while the work accomplished by earth-worms in turning over the soil has been exaggerated, that of the ant has been underestimated or overlooked. "I strongly suspect," he remarks, "that if surveys were made of the Irish lands where the earth-worms do work, and where the ants do work, the area of the latter would come very nearly equal to that of the first, while the soil in the ant-hill would considerably exceed that in the worm-casts."

Fig. 6.—NESTS OF THE WHITE ANTS (*Termites*).

Coral Reefs, etc.—But perhaps the most remarkable of all the rock makers which are not actually rock wasters are those marine animals which, appropriating the limy matter dissolved in the sea, deposit it in their shells, and, when they die, aid, by the accumulation of their bodies, just as the "ooze" already described does, in building up solid strata. This is seen in the great beds of shell-fish which lie off the shores of most continents, such as the oyster "scalps," which, like those of the Racoon Bank off the Virginia shore, are often of wide extent and thickness. The Pearl Oyster beds, though not so large, are also included under this head. There are also in the depths of the ocean vast quantities

* This fact was noted by the late Mr. Gibson, of the Museum of Science and Art, Edinburgh, to whom I am indebted for some of the references to worm work used in the preceding pages.

of sea urchins and of stalked star-fishes or Pentacrini, which, when dead and consolidated with mud and sand, form a limestone in every respect—except of course in the species being different—identical with the encrinital and crinoidal limestone, which is so commonly associated with the Carboniferous Measures and the Trias formation. The Terebratula and Gervillia beds of the Muschelkalk, the Gryphæa limestone beds of the Lias, the Hippurite limestone of the Chalk, the Cerithium, and Littorinella limestone of the Tertiaries, and a host of similar formations, are thus easily explained by what we see going on at the present day (Vol. I., pp. 54, 55). Some peculiar Algæ (sea-weeds), like corallines, nullipores, etc., also encrust their organic matter with carbonate of lime, extracted from the sea in which they grow (Vol. I., p. 55), and in some parts of the world—among the Florida reefs, for example—are forming by their abrasion considerable deposits of matter, which in time may become a more or less pure limestone. It is even possible for fresh-water deposits of this character to be laid down, since apart from the causes which form marl, some fresh-water plants—the Charas, for instance—encrust themselves with lime, and this, when they decay, must in course of ages form considerable layers of calcareous matter, in the shape of the hard parts of the plants embedded in the mud which has been deposited with or over them (Vol. I., p. 55). Some mosses—such as species of *Hypnum* and *Bryum*—and other water plants—like *Potamogeton* (pondweed), etc.—encrust, or, to use the incorrect language of the "curiosity collector," "petrify" themselves with the carbonate of lime held in solution by the water in which they grow, so that at Weissenbrunnen, near Schalkau (Germany), there is a compact sinter made by *Hypnum molluscum*, and a more porous one by *Didymodon capillaceus*,* while in various parts of Great Britain *Hypnum commutatum* acts in a similar fashion.

Characteristics and distribution of reef-builders.—However, all these organic rock makers of modern times sink into insignificance beside the polyps which create the coral reefs and islands that form such remarkable features in the tropical and semi-tropical seas. Considerable tracts in mid-ocean or off the shores of continents, and inhabited by prosperous peoples, are, with the exception of a thin layer of vegetable mould on the surface, composed entirely of calcareous matter, which these minute creatures have extracted from the sea for the purpose of forming the cases in which they live, and which, by working millions and millions of them in partnership, they have gradually reared into a vast organic mass. These animals belong to the same group as the sea-anemone, and in general terms may be described as zoophytes with cylindrical bodies, at one extremity of which the mouth, surrounded with one or more series of tiny arms or tentacles, is situated. They are thus of the Radiate order, and in no respect deserve the name of "coral insects," which is sometimes applied to them in the works of uninstructed travellers. Looking down into the clear sea which they love, the thousands of polyps in a lump of living coral, each with its little circle of expanded tentacles, look like a submarine flower garden. Among them swim fishes of varied hues and shapes, or scuttle crabs of equally bizarre form. If one could imagine a myriad of sea-anemones, each with a limy skeleton, and all consolidated into a single mass, in every essential except the size of the polyps we should have a coral reef. The corals bud one from another, thus expanding laterally, and as they add to the depth of their limy case, as circumstances dictate, and, until the heat of the sun gets too much for them, always build towards the surface. A passing cloud will oftentimes compel these sensitive zoophytes to instantly retract their fringe of tentacles, or a touch will, as in their more Northern relatives, equally compel a temporary retreat into the cave. Most of the reef-building species cannot bear exposure for any length of time to the air, though some can, like sea-anemones and others of their relatives in British seas, tolerate the withdrawal of the sea between tides. The

* Cohn, *Neues Jahrbuch etc.*, 1864, p. 580.

most common genera of reef-building corals are *Astræa, Porites, Madrepora, Millepora, Meandrina, Carophyllia,* etc.,* which are of all shapes—flat, tubular, oval, and irregularly-formed. The *polyparium,* or coral polyp structure, consists of two parts: the external living fleshy—or apparently fleshy—envelope, bearing and containing the polyps, and an internal solid, inorganic axis. The base of the attachment is large and fixed, and the branches subdivided for the most part, sometimes jointed, and always calcareous, while the animal which forms the limy structure inhabits an apartment or aperture in its compound house (Fig. 7).

The reef-building corals are, however, not of universal distribution. Corals of some species—relatives more or less remote of those which form the islands—are found in almost every sea. But those which at present concern us are confined within the isotherms, or lines of equal temperature, represented by a mean yearly heat of 63°, and in which the mean temperature of the sea is not lower than 68°. These conditions only prevail within about 30°—1,800 miles—north and south of the Equator. Hence, we do not find coral reefs in the South Atlantic, while they abound in the Pacific and Indian ocean, and along the eastern shores of Africa, Central America, and Australia. Madagascar, the Persian Gulf, and the Red Sea, are also favourite quarters of theirs (*See* Coloured Plate of the Red Sea Corals in Vol. I.), though the headquarters of the reef-builders may be described as Polynesia, where they have been principally studied, and to which the facts to be mentioned mainly apply. In the Pacific, besides extensive reefs round other islands, it has been calculated that there are 209 coral islands, and though there are no coral islands properly so-called in the West Indies, and along the Florida coast, there are many reefs of considerable size.

Other conditions, however, besides temperature, govern the distribution of the reef-builders. When cold currents sweep a coast, even when it is within the isotherms mentioned, corals shun it. Hence, the west coast of South America, which is laved by a cold extra-tropical current, is deficient in reefs. Muddy or alluvial shores are also unfavourable to their growth, for the polyps demand clear water and a foundation to build upon more solid than river deltas can generally supply. For this reason the vicinity of the great rivers emptying along the north-eastern coast of North America, and around the shores of the Island of Trinidad, are not fringed by these reef-builders, though the other conditions necessary for their growth are present. Furthermore, as the polyp cannot thrive in water which exceeds a depth of from fifteen to thirty fathoms, it necessarily follows that they cannot begin to rear their structures if the bottom immediately off any shore suddenly sinks to a greater depth than what we have noted. Hence, also, the coral polyp cannot begin to build in mid-ocean. When islands formed by them are found in such situations as many of the Polynesian ones are, we are entitled to conclude that the animal commenced its labours when there was bottom at a comparatively slight depth, or that the reef rests on a shoal water foundation. The polyp must also have food and the calcareous material on which to draw for the construction of its polyparium. For if it built from generation to generation in absolutely still water, it would soon exhaust the salts of lime in the adjoining sea. Accordingly, where the warm tropical currents prevail, there the coral flourishes; for it is by their agency supplied at once with food for itself and lime for the hard skeleton, in which we, as physical geographers, are more particularly interested.†

Fringing reefs.—The result of this building

* The Mediterranean red coral of commerce (*Corallium nobile*) is not one of the reef-building species. It belongs, indeed, to an entirely different group (the *Alcyonaria*), while the latter are included in the *Zoantharia.*

† Darwin: "The Structure and Distribution of Coral Islands" (1874); Dana: "Corals and Coral Islands" (1872); Nicholson: "The Structure and Affinities of the Tabulate Corals" (1879), and "The Structure and Affinities of the Genus Monticulipora" (1881); Klunzinger: "Die Korallthiere des Rothen Meeres" (1877-79); Haeckel: "Arabische Korallen" (1873); Mosely in *Challenger* Reports, Vol. II.; Quelch in *Ibid.*, Vol. XVI., etc., etc.

upwards and outwards is that either off the shores of continents, or off or encircling the shores of islands, are great banks of hard coral rock, partly full of living animals, but above and at more than fifteen or twenty fathoms below the surface composed of dead coral. These are known as "reefs." Charles Darwin, who was the first traveller who studied these structures

Fig. 7.—DENDROPHYLLIA RAMEA (DEEP-SEA CORAL).

from the geologist's point of view, has divided them into (1) *fringing reefs;* (2) *barrier reefs;* and (3) *atolls.*

The first-named (Fig. 8) are seldom of such gigantic size as the others, and they may

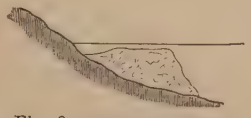


Fig. 8.—FRINGING REEF.

either surround islands, or simply skirt or fringe the shores of continents. They are essentially coast reefs, with only a shallow channel between them and the shore, while the soundings on their seaward side indicate that they rest on a gently sloping surface. Sometimes—as in the reef around the Island of Mauritius, which lies at a distance of half a mile or so from the shore—the channel is in parts so shallow that there is no difficulty in wading across it at low water, and in no place does it exceed 10 or 12 feet in depth. The coral reefs of the Red Sea are examples of this order of reefs, and we find similar ones off Ceylon, the Nicobar Islands in the Indian Ocean, off the West Indian Islands, and the Peninsula of Florida.

Barrier Reefs.—The barrier or wall reefs (Fig. 9) are in most respects like the foregoing ones. That is, they may either encircle islands or skirt the shores of continents. But they are distinguished from them by being at a much greater distance from the land, and consequently possessing a deeper and broader channel between their shore side and the

nearest land, while the soundings on their seaward side indicate a much greater depth

Fig. 9.—BARRIER REEF.

than in the preceding case; though the early accounts which described the sea at a short distance seaward from the reefs as "unfathomable" are not quite correct. They are also of considerable breadth: the polyps seem to build from the shore outward, until the increasing depth renders it impossible for them to live. The barrier reef, if it surrounds an island, is usually known as "encircling barrier reef," and the land surface in the centre of this more or less continuous ring of coral is described as a "lagoon island."

Such an arrangement forms a natural harbour of the most perfect character, for once inside the barrier of coral—and there are usually several openings in it—the vessel is as safe as if it were surrounded by an artificial breakwater. Hence the excellence of the accommodation afforded for shipping in the high islands of the South Sea, the Carolines, New Caledonia, the Fijis, Samoa, the Society Islands (Tahiti), etc. These reefs are usually much longer than broad, while their elevation above the sea is seldom more than from ten to thirteen feet, when the reef is generally covered with a luxuriant vegetation of cocoanuts and other native plants, which flourish in the thin layer of soil formed by the droppings of sea birds, the decomposition of forests and plants drifted by the currents, or blown by the winds, and the decay of the vegetation which has in time established itself in this seaborn surface. The reefs on the north side of the Fijis are from one to four miles broad, while that off the west coast of New Caledonia extends from about 150 miles to the north and 50 miles to the south of the islands, its total length being 400 miles, with an average distance of from 8 to 16 miles between it and the shore. At two ships' lengths from the seaward side of the reef no bottom was found at 150 fathoms. The Great Barrier Reef off the north-east coast of Australia extends, with few breaks, for nearly 1,250 miles, with an average breadth of 10 to 90 miles, and a width of channel between it and the shore of from 20 to 30 miles, though in places the width of the interval extends to 50 and even to 70 miles, with a depth of from 10 to 60 fathoms, while the sea outside is in places 300 fathoms deep. Reefs of this description must therefore be in some instances at least 1,000 feet thick.

Atolls.—Atolls or Lagoon reefs—the first name being of Maldive origin—are generally

Fig. 10.—STEWART ATOLL, OR SIKIANA (LAT. 8° 22′ S.; LONG. 162° 58′ E.)

C, Reef Channel; *F*, Faule Island.

oval or roundish circles of coral, with here and there a break in their continuity, enclosing a lake-like expanse of water, without any land. (Figs. 10, 11). Hence the name of lagoon (Vol. I., p. 71). The lagoons of Lakena

Fig. 11.—SECTION OF THE CORAL REEFS OF FAULE ISLAND.

a, Outside; *b*, Inside.

(Ellice Group) and of Quiros Island (lat. 11° 2′ S.) are entirely shut off from the sea, and in both of them the water is fresh.

Whitsunday Island (Fig. 1) is a specimen of a type—not common—of a more or less continuous ring of coral now covered with

tropical verdure, without any land surface being seen. More frequently (Fig. 12) the atoll consists of a circular group of islets, each composed of coral. Outside, the sea is often very deep, the lead sinking — as off Cocos-Keeling Atoll—to 1,200 fathoms at a distance of 2,200 yards from the edge of the reef, while the still lake-like lagoon inside is in some places two, and in no part more than seven

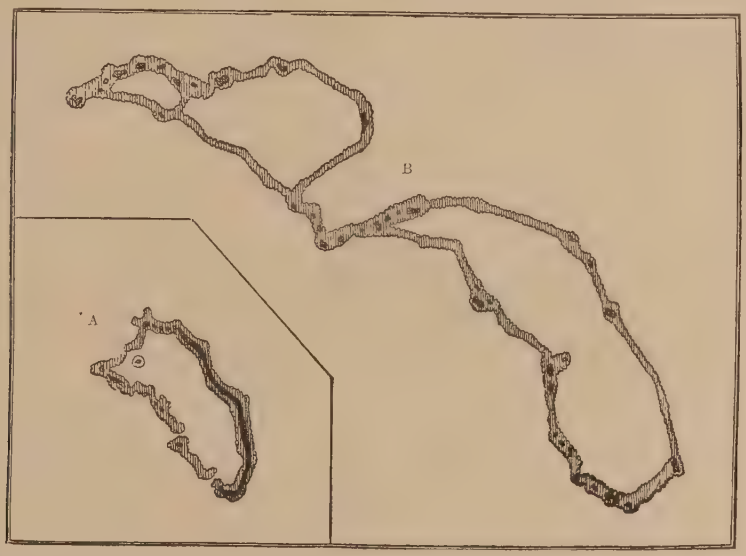


Fig. 12.—A, CHARLOTTE ISLAND, OR APIA, IN THE GILBERT ARCHIPELAGO; B, NAMU AND LILEB, OR THE MENTSCHIKOFF ISLANDS, IN THE MARSHALL ARCHIPELAGO.

fathoms deep, while in sections it is shoaling rapidly.

Such a basin, with its deep, clear channels through the reef—affording (as many of them do) room enough for all the navies of Christendom to ride at anchor—supplies the very perfection of harbour accommodation, even though the surrounding reefs are so low that during storms the breakers outside will dash over the massed wall of coral. In this lagoon marine animals of all sorts—including fishes, and pre-eminently sharks—swarm; but it is seldom that the wind disturbs the water, with its smooth, glassy expanse, and curiously enough the openings in the reef are always on the leeward side, that is, in the one least exposed to the prevailing winds, so that while a ship has no difficulty in getting out to sea, it sometimes happens that it does not find an escape from the storm so easy. These "reef-channels" are produced by various causes—swift currents interrupting the growth of the coral, decay of the coral from local causes, such as the poisoned water which is often noticed in a volcanic neighbourhood, and other natural or accidental interferences with the life of the polyps.

Atolls are frequent in the Paumotu group (Fig. 13), in the Carolines, in the Radack, Ralick, Kingsmills, in the Pelew Islands, etc. Stewart's Atoll (Fig. 12), in the chain of the Solomon Islands, is a good specimen of them. So is Apia, or Charlotte Island, in the Gilbert Archipelago (Fig. 12, A); while a third typical example of the Atoll reef may be cited in the Mentschikoff Islands (Fig. 12, B). The largest group of atoll islands—which only differ from the encircling barrier reefs in not enclosing any land—exists in the Laccadives, Maldives, and Chagos group in the Indian Ocean, though the Cocos-Keeling Atoll,

which was carefully examined by Darwin, and still more recently by Henry Forbes, is among the most instructive and best known.*

Origin of Coral Reefs.—*Darwin's Theory.*—On examining a coral reef it is seen that the seaward side is steep, while on the landward aspect it presents a long and gentle slope. On the former side the reef is subject to continual attack from the sea. Never for an hour does the dash of the surf cease, the roll of the ocean breaking on the barrier in an unbroken line extending along its entire length, the waves curving towards the shore in a graceful arch which glitters in the sun. "This beautiful water structure then disappears with a loud and hollow roar into the reef, only to be succeeded by another and another."† Indeed, so terrible is the onslaught of the sea on these coral reefs, that the wonder is how they have ever managed to survive the ceaseless attack of the breakers. As Mr. Darwin has remarked, no period of repose is granted; the long swell caused by the steady action of the trade-wind never comes to a stop. The breakers also exceed in violence those of the North, so that when we remember how ordinary rocks yield to these watery blows, it appears almost certain that, while the reefs made by the polyps resist all the force of the waves, neither granite nor quartz could long survive such irresistible forces. "Yet these low, insignificant coral islands stand, and are victorious, for here another power, as antagonist to the former, takes part in the contest. The organic forces separate the atoms of carbonate of lime, one by one, from the foaming breakers, and unite them into a symmetrical structure. Myriads of architects are at work night and day, month after month, and year after year, and we see their soft, gelatinous bodies, through the agency of the vital laws, conquering the great mechanical power of the waves of an ocean, which neither

Fig. 13.—MANGAREWA OR GAMBIER ISLAND IN THE PAUMOTU ARCHIPELAGO. (MOUNT DUFF IN LAT. 23° 8′ S., LONG. 134° 55′ W.)

a, Atoll-like barrier reef connecting a number of higher islands; *b*, Low coral islands; *c*, Fringing reef off higher islands.

* Forbes: "A Naturalist's Wanderings," pp. 35–41.

† Cooper: "Coral Islands," Vol. I., p. 25

the art of Man nor the inanimate works of Nature could successfully resist."

Outside this line of breakers the sea, we have seen (p. 16), invariably indicates vast depth, though on the landward or inner side of the reef there is peace, and only a very moderate depth of water. What is more, the living corals do not occupy the entire body of the reef. The polyps only flourish along a strip at the seaward margin of it, covered at extreme low water, since very few of them can stand exposure to the sun. All the rest of the reef is—for reasons already mentioned (p. 13)—composed of dead coral, though owing to the infiltration of water into the porous mass, and the filling up of every opening with the dissolved out calcareous matter, a lump of dead coral presents a solid crystalline structure which makes it an excellent building-stone.

It is therefore clear that if the polyps cannot build higher than within a certain distance of the surface, and, of course, not at all above it, we must look to other causes for the origin of those reefs which are raised several feet above the sea. This agency is usually considered to be the action of the breakers, which tear off fragments from the seaward edge of the reef, and heap them up, until in time the mass rises above the surface of the waves, and becomes compacted by the former detritus of the reef, and cemented by the percolation of water holding carbonate of lime in solution. However, if there was no other force at work, it might happen—indeed, could hardly fail to happen—that the sea would in time undo what it had done. But the force necessary to counteract this abrasion is supplied by the vital activity of the living corals, which form the seaward margin of the reef, and which, by their growth, prevent the sea from *always* destroying the heaped-up lumps of coral, and the broken coral sand which it may have thrown up.*

It may also be remarked that the openings in reefs—the reef channels through which ships gain admittance—are almost invariably opposite valleys, where—in barrier and fringing reefs—streams of fresh water flow from the mountain. Here, also, the tallest cocoanut trees often grow, acting in the way of beacons, which show the native fisherman where he can get shelter and fresh water.

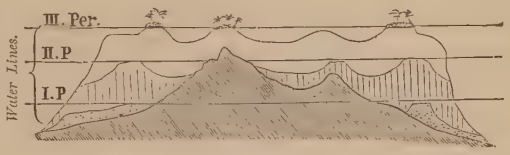


Fig. 14.—DIAGRAM ILLUSTRATING DARWIN'S THEORY OF FORMATION OF THE THREE FORMS OF CORAL REEFS.

First period, the Fringing Reef; second period, the Barrier Reef; third period, the Atoll.

These facts are not unimportant in considering the origin of the different kinds of reefs.

It also follows, from what we have said regarding the impossibility of corals living at a lower depth than 30 fathoms, or in some cases half as low down, that they could not begin to build their reefs on the bottom of the sea. How, then, do we account for the fact that some reefs are a thousand feet or more thick, and that outside of their sea-margin the lead sinks into the greatest profundity? Various answers have been proffered to the question; but until lately none of them were in any way so satisfactory as that of Darwin, whose theory of the formation of coral reefs ranks as one of his first and certainly not one of his least important contributions to the history of creation. In a few words, his view is that the Barrier Reef and the Atoll are simply stages of the Fringing Reef, due to the continuous sinking of the foundation on which it is built. The polyps build a fringing reef in comparatively shallow water to within a few feet of the surface. Then by the dash of the breakers it is mechanically raised above the surface in the manner already described. But all the time it is sinking—the apparently stationary character of the reef being due to the action of the polyps building upwards almost as fast as the ground on which they have reared their composite dwelling subsides. However, in time the channel between it and the shore will broaden and deepen, and if the reef lies off an island, the top of the island will, after a number of years, begin to

* Nicholson: "Manual of Zoology" (1887), p. 193.

show the effect of this sinking in the shape of a decreased area, since the island has no vital action to counteract the subsidence going on. In other words, the fringing reef has become a barrier reef. If, however, the subsidence continues, the top of the island will altogether disappear, and the reefs, which in an earlier stage of their existence lay off the coast, will encircle, in a more or less complete manner, a lagoon-like expanse of water. In short, the barrier reef has become an atoll (Fig. 14). Any further subsidence will produce little change in the atoll except, perhaps, a diminution of size. This theory is in accordance with the circumstances which obtain over the area in which coral islands are for the most part found. The Coral Sea extends in a line marked by atolls for some 4,500 miles, in an ocean notable for its volcanic peaks, and in many instances for volcanic eruptions (Vol. I., p. 167), which, we have already learned, are closely related to oscillation of the Earth's crust. The facts mentioned also explain the existence of valleys opposite the openings in barrier reefs. For, as the coast is naturally lower at the mouth of valleys, the subsidence which will lower the rest of the reef will entirely submerge it at such places.

Murray's Theory.—Until recently, Darwin's theory was almost universally accepted, and even yet is generally admitted to be the one which explains the greatest number of phenomena connected with coral reefs. It is, however, beginning to be recognised, owing to the observations of Agassiz, Semper, Guppy, and, above all, of Murray, that however plausible the Darwinian theory of coral reefs is, facts do not in every case fit in with it. For instance, if the peaks on which the reefs are built are remnants of a vast submerged continent, it would hardly fail that some traces would be found on their flanks of strata other than volcanic. Yet that is not the case. Lavas and tufas are the only rocks seen on the islands along which fringing and barrier reefs lie. What is more, there is no proof of the gradual subsidence which is essential to Darwin's theory. Dr. John Murray is, therefore, inclined to hold that all the different forms of reefs grew upon foundations just where they found them, their foundations not being the remnants of submerged continents, but volcanic hills vomited out of the sea in the manner which we have already discussed (Vol. I., pp. 163–167). "Whether built up sufficiently high to rise above the surface of the sea and thus form islands, or brought up only to varying heights below the sea level, these volcanic eminences tend to become platforms on which coral reefs may be formed." This, Dr. Murray contends, must necessarily happen from the action of the tides and waves, tending to reduce all volcanic summits down to the lower limit of breaker action, thus producing platforms on which barrier reefs and atolls may spring up. Again, as the continuous deposition of volcanic and organic detritus, the ooze already described (p. 4), goes on, submarine eminences may be brought up to the zone of the reef-builders; this deposit of foraminifera, etc., also supplying an ample stock of material for the construction of the coral polyp's limy cases. In the surface waters of the Tropics, Murray calculates that in an area one mile square by 100 fathoms deep, there are 16 tons of carbonate of lime existing in the form of the shells of foraminifera and mollusca. Atolls, indeed, tend to form on a reef formed by the destruction of a volcanic peak raised, like Graham's Island (Vol. I., p. 165), just above the surface of the waves; for on the outside of this reef the waves break fiercely, and it is in such localities that the coral polyp flourishes best, its life inside the lagoon being languid. Accordingly, working as it does on the periphery of such a reef, it will in time form a more or less complete circle of coral. The windward side of a reef grows most vigorously, not because it receives a greater amount of oxygen through the greater aëration of the water, but simply because it is on that side that the currents bring the greatest amount of food to the polyp makers. As the reef grows seaward the lagoon enlarges, owing to the seaweed brought in by the tides, laden with carbonic acid gas, acting on the dead coral, and thus removing the lime in solution. Murray, therefore, regards the

Laccadive, Caroline, and Chagos Archipelagoes, as various stages in the growth of the corals to the surface, and considers the various appearances in the Maldive group of atolls as explicable without any necessity for dissevernment by oceanic currents, etc., as argued by Darwin. A barrier reef, the same ingenious observer contends, commences in shallow water near the shore, and afterwards extends seaward on a talus built up of lumps of coral broken off by the surf.

In brief, to summarise Dr. Murray's views, he thinks that the characteristic forms of barrier reefs and atolls are in no way dependent on subsidence, that these reefs may be found in areas of subsidence and in areas of elevation, and that elevation and subsidence only modify in a minor degree the appearance of the islands. What really determine their shape and character are (1), the vigorous growth of the reef-forming corals on the seaward face of the reef where food is abundant, and the much less vigorous growth—or even death—of those on the inner edge of the reef and in the lagoons where food is scarcer and the conditions less favourable to growth; (2), the removal of lime in suspension and in solution from the inner portions of the reefs, and from the lagoons, by sea-water containing carbonic acid.* This view is, however, still *sub judice*. It has shaken our belief in Darwin's theory, but at the same time, while it unquestionably explains some of the phenomena described, it leaves others still unsolved, and does not render the old doctrine entirely inapplicable in not a few of the cases cited in proof of its fallibility. The fact of atolls at one extremity of a group (in the Pelews, for example), and sixty miles away raised coral reefs, is also against Darwin's theory. In the Solomon and Loyalty Islands there are elevated coral reefs at all heights, from 100 to 1,200 feet, of a structure which tend to give confirmation

Fig. 15.—GROUND PLAN OF BOLA-BOLA ISLAND, ONE OF THE SOCIETY ISLANDS.

(*From Darwin's "Coral Reefs."*)

to Dr. Murray's theory, while the discovery of coral at a considerable height in Viti Levu, in the Fijis, and elsewhere, is more favourable to the theory of the islands being elevated than being sunk.

Professor Dana, it may be mentioned, is by no means convinced that Dr. Murray and the other opponents of the old views have made out their case. On the contrary, this distinguished student of corals is of opinion that "all the hypotheses of objection to Darwin's theory are alike weak, for all have made these processes"—namely, abrasion and solution—"their chief reliance, whether appealing to a calcareous, a volcanic, or a mountain-peak basement for the structure. The subsidence which the Darwinian theory requires has not been opposed by the mention of any fact at variance with it, nor by setting aside Darwin's arguments in its favour; and it has found new support in the facts from the *Challenger's* soundings off Tahiti that have been put in array against it, and strong corroboration in the facts from the West Indies."† Darwin also died unconvinced that the actual facts recorded by Dr. Murray are absolutely inconsistent with his own theory of subsidence, or

* Murray, *Proceedings of the Royal Society of Edinburgh*, Vol. X., p. 505; and Article "Pacific" in *Encyclopædia Britannica*, Vol. XVIII., pp. 128, 129; Alex. Agassiz, *Transactions of the American Academy*, Vol. XI., p. 120; Semper: "Die Philippinen und ihre Bewohner" (1869), pp. 19–33, 100–9. Guppy: "The Geology and Physical Characteristics of the Solomon Islands" (1887); Rein, *Bericht. Senckberg. Nat. Gesellschaft*, 186°–70, p. 157, and *Verdhandlungen erst. deutsch. Geographentags*, 1881, p. 29 (*fide* Geikie); Arch. Geikie, *Proceedings of the Royal Physical Society, Edinburgh*, Vol. VIII., pp. 5–29 etc

† *American Journal of Science*, 1885, p. 190.

that these facts necessitated or supported the hypothesis advanced by that writer.*

Man and Coral Reefs. — The abrading action of the waves on coral reefs is seen in the immense blocks which are constantly being detached, in the great amount of coral sand and silt which, as in the Cocos-Keeling Archipelago, is filling up some of the lagoons (Fig. 16), and in the milky discoloration of the sea after a storm, often six or seven miles from the reef. This denudation is often fatal to low-lying atolls. Not unfrequently the great

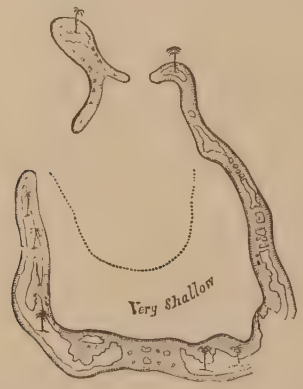


Fig. 16.—GROUND PLAN OF COCOS-KEELING ATOLL.

(*From Darwin's "Coral Reefs."*)

earthquake waves caused by subterranean disturbances have swept away the inhabitants of the Pacific atolls, and done much damage to the reef islands. Sometimes after a cyclone a little coral islet is entirely destroyed, but, as in the case of Workhouse Island in the Cocos-Keeling group, for example, becomes replaced in two or three years. This proves that, in some instances at least, the floor on which the coral reef is built, instead of sinking, actually rises. If this be admitted—and, considering the oscillation going on in any volcanic region, there need be no reluctance in accepting the assumption—there disappears at once the difficulty often felt in understanding how some reefs are raised above the surface, since it is clear, from what we have learnt of the polyp's conditions of existence, this could not be effected by them. On a subsiding or stationary foundation, a reef can never by any luxuriance of its own growth rise above the high-water level and become a coral islet fitted for the growth of plants, and eventually for the habitation of man and other animals. Great storms, however, by breaking off huge blocks of coral from its living and ever seaward-growing margin, and piling them on the lagoonward portion of the reef, raise the surface above the sea, and enable the new-born islet to become fitted for the reception of the ingredients of soil. If, however, the islet is destroyed, this process must be very slow, for if the Florida reef was, as Alexander Agassiz estimates, built to the height of only forty-two feet in 1,000 or 1,200 years, it would have been quite impossible for Workhouse Islet to be renewed in two or three, as Mr. Forbes tells us was the case. What is more; if all atolls are sinking, or even stationary, it passes our understanding to explain why the interior margin of the island is elevated several feet above high-water mark and shows no sign of sinking. "As a storm so violent as the cyclone of 1876," Mr. Forbes writes, speaking of the Cocos-Keeling group, "was capable of pushing the torn-off blocks of the reef floor, composed of a natural concrete of worn coral, shells, and the hard parts of pelagic animals, embedded in a solid, calcareous matrix, *only a few yards* over the higher edge of the island, it is impossible for the lagoon margins, in some places more than 800 yards distant from the sea, to be kept up in elevation by the *débris* of the outer margin; and the greatest storms do not affect perceptibly or permanently the shores of the lagoon." These facts afford strong evidence that, whatever might have been the case with their kindred elsewhere, the Keeling reef and those in the Loyalty Islands, have risen, and that the Darwinian theory of coral reefs does not fully apply to them.

But whatever may have been the process by which the coral reef becomes a coral island, the methods by which it gets covered with soil are the same. The coral mud or powder

* "Life and Letters of Charles Darwin" (1887), Vol. III., pp. 181–183; Judd: *Nineteenth Century*, November, 1887, p. 640. In the same Number Professor Huxley discusses this and some cognate matters in dispute.

is in itself unfitted for the growth of plants. But in great storms sea sand may be thrown on the atoll, and mixed with the lime of the coral, to an extent capable of fitting the resultant soil for the growth of cocoanut-trees, many of which on the coast of Africa and elsewhere grow in pure sand or silica. But the sea birds also rest here, and mingling their excreta—and their dead bodies also—with the slender coating thus formed, still further enrich the accumulating humus. The waves bring it bunches of floating seaweed, the currents drift wood from far-away shores, and the winds—especially cyclones—and the waves combined convey the light seeds of plants and leaves carried from the nearest continent or from contiguous islands. Land birds also bear in their crops, in their plumage, or, as in a well-known instance, in the clay attached to their feet, the seeds of the country from which they have last flown, and depositing them in the growing soil form the beginning of a vegetation which, dying, helps to make a mould. This the tropical rains refresh, and, sinking into the reef, form wells, from which a tolerably certain supply of water can be obtained.

For ages this process of alternate growth and decay may go on until the soil has grown richer and richer and the atoll ring is marked out by a thick circle of cocoanut and other trees, which have sprung up from the forests tossed by the sea on the new-born shore (Figs. 1, 18). In the roots of the drifting trees — Oregon pines are cast up on the Sandwich Islands—are conveyed land shells, and even the eggs of reptiles and other animals, which add their quota to the fauna of the atoll. On these islands earth-worms are, as might be expected, absent. But several species of land-crabs serve much the same purpose in the economy of Nature, soft limy mud flats becoming covered with soil mainly by their agency, and, as Mr. Forbes thinks is the case in the Cocos-Keeling Islands, by slow elevation. On West Island the lagoonward portion is tenanted by two if not three species of *Gelasimus*, which live in narrow corkscrew burrows, round the top of which

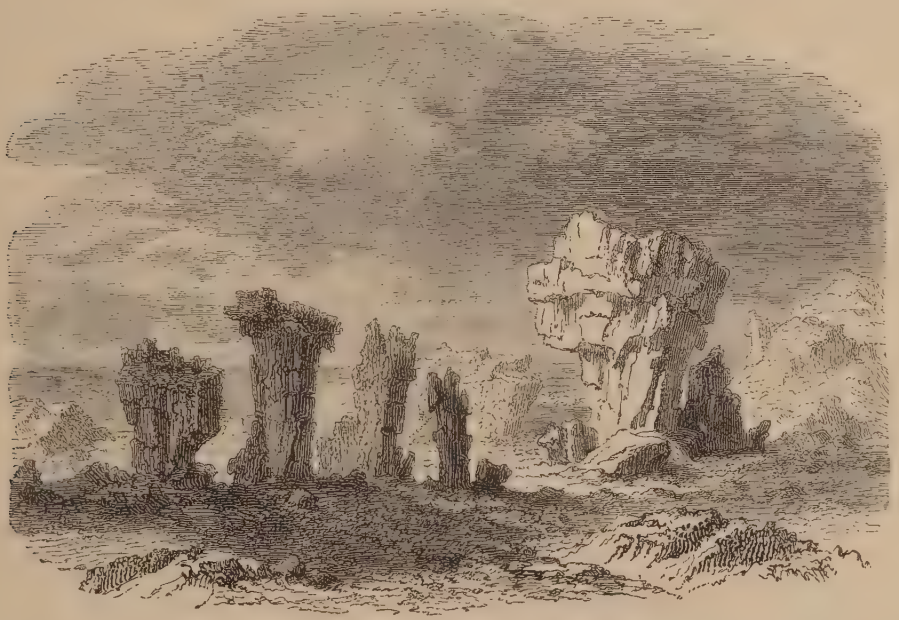


Fig. 17.—WEATHER-WORN ELEVATED CORAL ROCKS IN THE PAUMOTU ARCHIPELAGO. (*After Wilkes.*)

this explorer of the Malay Archipelago tells us there is always a little mound, just as there is about an earthworm's hole. In two square feet of ground 120 of their holes were counted, and as there are acres thus riddled, the number of this active army may be imagined. During the retreat of the tide, and even during high water, they are incessantly busy bringing down twigs of trees, fronds of sea-weeds, burying smaller particles of vegetable rubbish, it lowers down considerable branches of trees, and even cocoanut palms, by scooping out the soil below them. The seeds of the iron-wood tree (*Cordia*) are also borne off by it, and hence the two trees named, along with a rough sort of grass (*Lepturus repens*), and the hard-wooded *Pemphis acidula*, are the pioneers of the plants which occupy the lands wrested

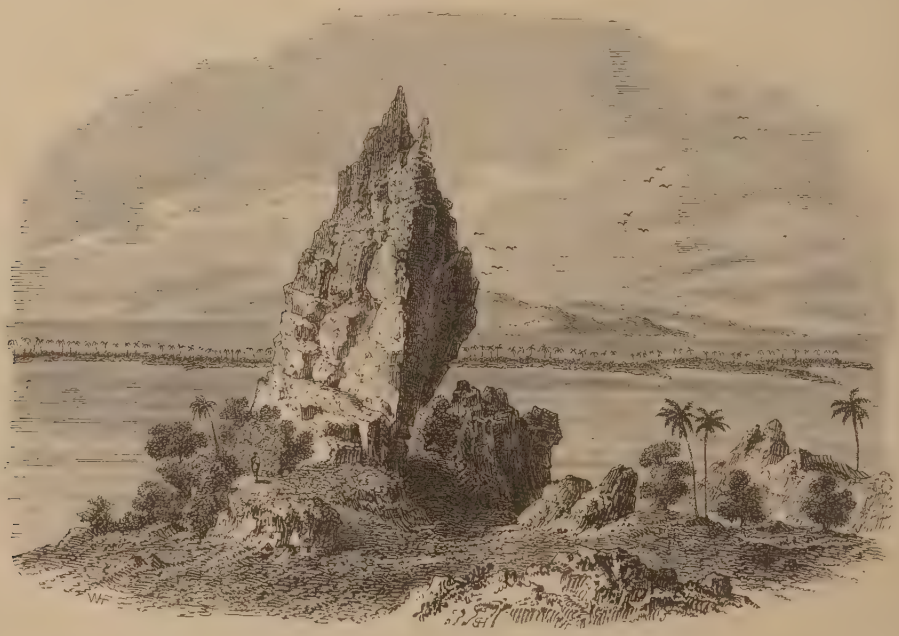


Fig. 18.—ISLAND OF BOLA-BOLA (3,945 FEET), SHOWING FRINGING REEF. (*After Duperrey.*)

scraps of cocoanut shell, and seeds with which to lay the foundation of the future land. Between tide marks, but extending its operations farther landward, another crab (a species of *Macrophthalmus*) is busy at the same work, one-third of its time being spent under water, and two-thirds in energetically mining burrows, tossing out the sand from and carrying into them all sorts of vegetable *débris*. The area along the dry margin of the land is occupied by a third species of crab (*Ocypoda*), the labours of which in the interest of dry earth are even more effectual than those of the two already mentioned. For, besides from the sea by these industrious crabs. "As soon, however, as its busy labours have changed the white calcareous fine shore into a dark vegetable mould its occupation seems gone, and it retires in quest of new land to conquer." Farther from the sea a fourth species—a *Gecarcinus*—tills and turns up to the sun and rain the thin layer of vegetable mould, rarely visiting the water, and then only in times of great drought. Finally, the *Birgus latro*—the great cocoanut-"stealing" crab—(Fig. 19) does doughty service in the humble *rôle* assigned it as a world maker. Chiefly nocturnal in its habits, this shore crustacean digs

deep tunnels in the ground, larger than rabbit burrows, which it lines with cocoanut fibre, though it is a slander on the crab to affirm, as its name seems to do, that its object in climbing the trees is to rob them of their nuts; it lives on those which have fallen.

By-and-by, when the island, by whatever means, is fitted for man's support, a canoe may be cast away, or some junkmen, as has happened so often in the history of Japan, are driven out of their course and find an asylum on the hitherto unknown coral islet, or they light upon it when making one of their long voyages for which the New Hebridean and Caroline Islanders are famous, and return to it with their wives and children. Then

Fig. 19.—THE COCOANUT-"STEALING" LAND-CRAB (*Birgus latro*).

by-and-by comes the trader, and after him the missionary and the teacher arrive, with the blessings and the curses of civilisation which so often follow in their train.

A coral island is, therefore, as Mr. Dana puts it, "but a miserable place for human development, physical, mental, or moral;" for as culture almost invariably comes from without, and does not originate within, a people who are shut off from the rest of the world must depend on their own resources for new ideas, as well as the materials by which these ideas can be made conducive to "the good of man's estate."

CHAPTER II.

Geological Formations and the Fossils they Contain.

The Classification of the Strata composing the Crust of the Earth—How we know that one Rock is Older than another—The same Strata never repeat themselves—The Law of Superposition—The Sunday Stone—Fossils—What they are, and the Facts regarding the History of the World which can be Deduced from Them—Fossil Animals—How they got Engulfed in the Material composing the Beds in which they are Found—Inferences from the Parts Preserved and the Mode in which they are Fossilised—Fossils not necessarily Organisms—They may be Holes, Tracks, or Footprints—In a manner, Raindrops and Coprolites are Fossils—Ichnology—Illustrations of the Inferences derivable from the Study of Footprints from the way a Savage obtains Information from a Trail—Caves, Bogs, etc.—Examples of Animal Destruction in Modern Times—Fossilisation of Animals—Different Modes in which this has been Effected—Plants—Different Modes in which they have been Preserved—Göppert's Experiments—Possibility of Igneous Rocks Holding Organisms, etc.

The preceding pages have been, for the most part, occupied with the consideration of what have been termed geological agents—in other words, the forces of Nature which are at present rough-hewing and chiselling, tossing up and laying down, the crust of the Earth and the materials of which it is composed. These, we have shown, must always have been at work, and to them, acting in the manner described, must be attributed the various beds of rock, and the various outbursts of unbedded matter which intersect them, or in some instances are interstratified with them. It therefore follows that if we could obtain at any one spot a cutting or "section" through the Earth's crust we should find reposing upon the igneous mass, which may be regarded as the pristine material out of which all the others have been worn, or in some way made, a series of strata or beds, the lowest of which would necessarily be the oldest, while the topmost would be the youngest, and, probably enough, like the deep-sea oozes, in course of formation at the present day.

This opportunity, however, occurs at no one place. In some spots, in deep mines or sea cliffs, we have a chance of seeing a good many beds reposing one upon another. Yet these are at best but a few of the number making up the entire series. The circumstances prevailing at the time enabled only one or two to be laid down before the land was elevated, and if it was again depressed unnumbered ages might have elapsed, so that there would be a break between the last laid down and those following them corresponding to that lapse of time. However, the missing beds—as the geological agents never come to a standstill—would have been deposited somewhere else. But we have evidence incontrovertible, that thousands of feet of hard strata have, by the process of denudation and earth sculpture so fully described, been worn and washed away so that in many places where there are now mere undulations there were in some period of the Earth's history lofty plateaux, or great mountain ranges. We must, therefore, to obtain an idea of the succession

of the strata composing the Earth's crust, piece together the beds from this section and from that. Here, for example, we may find the bare granite showing itself on the surface, with not one bed above it. If there were ever any laid down they have long since disappeared under the action of denudation. At another place, what is known to have been the oldest of strata lie on the surface, and, at another spot, reposing on them without any intermediate ones, are what we are well aware must be regarded from the geologist's point of view as almost modern beds. Thus, by watching their opportunities all over the world, students of the branch of science with which we are at present concerned, have been enabled to put together their common stock of knowledge so effectively that it may be taken for granted that, though facts innumerable are still to be discovered, and modifications without end to be made, no extensive series of unexplored strata, or any new geological period, remain to be added to those which the investigators of the present century have brought to light.

A well-instructed observer can tell much of the history of a rock from looking at a cutting of it. If composed of sand he is entitled to draw certain conclusions as to the agent by which the particles composing it were worn from the parent rock; if of mud he is equally justified in making tolerably positive inferences as to the character of the river or sea in which it was laid down. The mineralogical composition of the beds also affords some clue to their origin, and in many cases—though not always—he may with some confidence infer that when two rocks exhibit either to the naked eye, or still better to the microscope, an identical structure, if not contemporary, they have at least been laid down about the same period and under conditions not widely different. If he further finds sheets of trap interstratified with them, he is compelled to conclude that there was a volcanic eruption between the time the upper and the lower beds were deposited. Furthermore, when one bed lies on the top of another, the inference is, if there are no signs of the inversion which we have already studied (Vol. I., p. 75), that the upper one is more recent than the under one. Again, it is perfectly certain when a section shows non-conformability (Vol. I., p. 77) that a vast interval of time must have elapsed between the time of the deposition of the lower and the upper strata, notwithstanding the fact of their contiguity. These data have already been more or less fully alluded to, when we had occasion to describe the various appearances which the strata present.

But the great fact ascertained by modern research is that though any particular bed may be wanting in any particular section, the remaining ones always preserve their order of superposition. For instance, to anticipate a little, a cutting may show Chalk, Carboniferous beds, and Old Red Sandstone (or Devonian), proving that a great many intervening strata were missing. But though a few miles away the next section might show London Clay, Chalk, Permian, Old Red Sandstone, and Silurian, it is perfectly certain that the beds would never occupy any other than their regular position. If we find Silurian or Old Red Sandstone, it is needless going down in the hope of finding Carboniferous beds, or when we reach Permian of fancying that the Cretaceous strata may be reached by boring a little deeper. Or to put the matter in a simpler way, we may pile one upon another the volumes of an encyclopædia, the first lowest, and the others in regular sequence as issued, until the twenty-fourth volume lies on the top. We might withdraw one here and there, until the series was imperfect, but still the sequence would be preserved, even though it ran two, five, six, seven, ten, twelve, thirteen, seventeen, nineteen, twenty, and twenty-one, the twenty-second, twenty-third, and twenty-fourth having been "denuded" by the librarian or borrowed without being returned. These facts are of the first importance, for they lie at the bottom of all attempts to classify rocks according to their age.

A familiar instance of what data may be derived from a rock may illustrate the foregoing lesson. In some of the Northern coal-

pits the roof of the mine is composed of limestone which, after the manner of limestone generally (Vol. I., p. 66), is constantly dripping in milky drops. These drippings fall into the undisturbed pools on the floor of neglected parts of the mine. However, during the week, when the men are at work, the coal-dust gives the white deposit a black hue. But on Sundays or holidays, the limestone having the pit to itself deposits a thin lamina of white. This goes on all the year round, so that the "Sunday stone," as the miners term the deposit when it dries up and becomes caked, exhibits a rude calendar of the workaday world beneath the surface, and as such it is often exhibited among the curiosities of the coal-pits. Visitors are pointed out that the thick black bands represents the six days of work, the thin white ones the Sundays, and the still thicker white one, sandwiched between the regular series, the time the men were out on strike, while the two pale bands, which might be mistaken for two Sundays in one week, are the visible record of the colliers having "knocked off for Newcastle races."

Thus in a small way the Sunday stone is a historical record, just as in a larger one the thick strata are of the times that are past. But while the reader of the one is assisted by known facts, the interpreter of the other must depend entirely upon the sagacity with which he makes his deductions. There are no doubt "sermons"—as well as poems, and tragedies, and meteorological chronicles — "in stones." But the preacher is silent: the oracle returns no answer to the dullard, who, having eyes, yet seeth not.

To carry this illustration still further, suppose the Sunday stone was thick enough and in other ways suitable for their preservation, its layers might contain the remains of insects which had found their way into the pit, *plus* various other rejecta, fragments of tobacco pipes, and so forth, all embedded in this rock, forming under conditions with which we are perfectly acquainted. A careful study of the Sunday stone would, therefore, reveal, in addition to the facts already mentioned, some data regarding the life of the pit and of the men who were contemporary with the layers in which their remains are found. In brief, these insects, etc., would be *fossils*, and serve the same purpose which the ancient animals and plants preserved in the strata forming the crust of the Earth do to the palæontologist* who examines them, and who, from their character, position, and distribution, deduces certain particulars regarding the history of the world at the time they lived, or were entombed, which could not have been inferable from a study of the mere mineral structure and bedding of the rocks themselves. This brings us to a very important department of geological science, namely, Palæontology—the study of extinct beings, and the light which they throw on the past history of our Earth.

Fossils and Fossilisation.

When we break a lump of granite, trap, or other unstratified rock, we never by any chance find in it anything in the shape of fossils, the plant-like discolorations sometimes seen in granite being invariably mere "dendritic," † or tree-like, crystallisations of some of its mineral constituents. In the earliest series of stratified beds, fossils are also remarkably absent, life having been at the period of their formation either not present on the Earth, or in the process of metamorphism the entombed plants and animals were destroyed, or were of too lowly an organisation to be preserved. But in all the beds above them, wherever the strata have been formed under conditions likely to engulf specimens of the organism then existing, we find fossils in greater or less abundance. In the lower beds the species are of a humbler type of structure than in the higher ones, and the species wider apart from those living upon the earth —or in the waters under the earth—at the present time than the contents of rocks nearer our own period. As we ascend higher

* Greek—*palaios*, ancient; *onta*, beings; and *logos*, a discourse or reasoning; hence, palæontology is the science of fossils (*fossus*, Latin—something dug up).

† Greek, *dendron*, a tree.

and higher in the geological scale, the beings who have left their remains in the rocks become more complex in structure, the lowly back-boneless animals giving place to those with back-bones, fishes to reptiles, and reptiles to birds, and birds to suck-giving animals, until in superficial beds, in the earth of caves, under the stalagmite of limestone caverns (Fig. 20), in peat-mosses, in the mud of lakes, or in the deltas of rivers like the Nile, we find in connection with species identical with those living in the neighbouring sea, or in regions near at hand, the vestiges of Man or of his works.

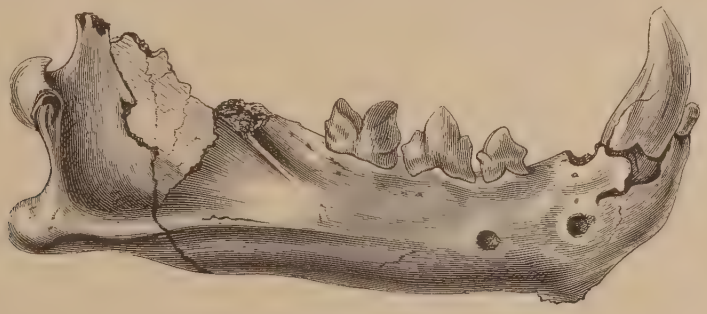


Fig. 20.—ONE-HALF OF THE LOWER JAW OF THE CAVE LION (*Felis spelæa*), PARTIALLY BROKEN.
From one of the caves of the Mendip Hills. (*After Boyd Dawkins and Sandford.*)

That these plants and animals are those which lived at the time the strata in which they are contained were deposited admits of no manner of doubt. In the early periods of intellectual speculation the wildest notions were entertained regarding their nature. They were, for example, considered the evidences of Noah's Flood, and for long a confiding world —simpler, more ignorant, less incredulous than ours—accepted a skeleton as "Homo Diluvii Testis," to use the title of the treatise which the once famous Scheuchzer wrote upon it. But so far from this fossil being "a proof of the Flood," it is now known to be the remains of a huge extinct salamander. Equally untenable is the solution which the Scotch quarryman gave to young David Livingstone,* that when "God made the rocks, He made the fossils at the same time," though indeed there exists among the curiosities of unscientific literature a bulky treatise by a naturalist of eminence in his own specialty, who, to avoid the necessity of attacking the problem, which might lead to a solution incompatible with his preconceived notions, actually ventures on an hypothesis scarcely less creditable to the Creator, namely, that they are *lusus naturæ* —freaks of Nature. In these times we have a better opinion of Nature than to suppose her capable of such elaborate idleness. Yet, in the second decade of this century, a very learned historian, though a very bad geologist, published a quarto volume which proved to the entire satisfaction of himself that the fossil bones of elephants and other wild beasts—all of extinct species, it ought to be added—which have been found in Britain, France, Spain, Siberia, and elsewhere, were the remains of those animals employed in the wars, ceremonials, and sports of the Mongols and Romans.

These foolish speculations were the "wild oats" of geological science, and are only now recalled as specimens of the ingenuity with which men otherwise capable of reason managed to avoid a plain issue. A "fossil," as we understand it, is a plant or animal "buried" —as the word implies—in the crust of the Earth by any agency other than man. Of those known—and the long list is every day being added to—about one-sixth belong to living species; that is to say, they are found in formations which geologically are of very

* "Missionary Travels," Introduction (1857).

recent date, though historically they are so incalculably old that their age is not computable in the figures with which the ordinary chronicler deals. They are found in all sorts of positions, though in none which would lead us to infer that they were not embedded in the ways already so frequently described in the preceding pages as capable of occurring when the materials of the stratified rocks were laid down.

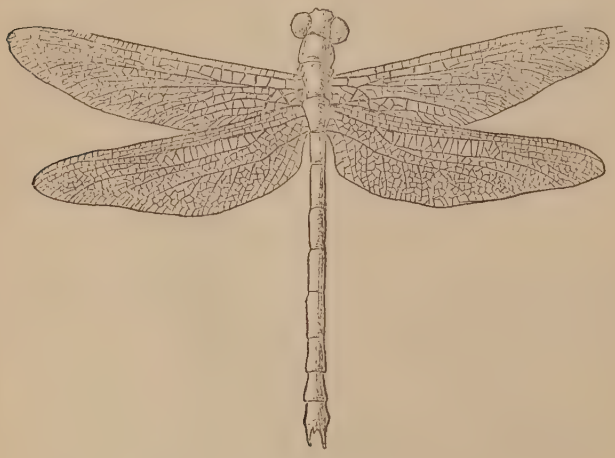


Fig. 21—AESCHNA MÜNSTERI, A DRAGON-FLY FROM THE LITHOGRAPHIC SLATES OF SOLNHOFEN.

How Fossils got Embedded. — *Animals.* Animals often get embedded in ooze or mud, or are washed down and entombed in the clay forming the deltas of rivers. In this case the soft parts will decay, leaving only an impression behind, while the skeleton and other hard parts remain. The skin of that great reptile, the Ichthyosaurus, remains fossilised in the Lias; while animals so extremely fragile as the jelly-fishes—little more than membranes full of sea-water—and insects (Fig. 21) have left traces of their presence in the fine lithographic slates of Bavaria, showing that at the time these beds were laid down the waters must have been extremely tranquil. In the sea also species are entombed, though the conditions under which they were embedded were not so tranquil, as we now know that seldom or never were the materials of the stratified rocks deposited in the placid depths of the ocean, but generally within a comparatively short distance of the continental masses, of which they are the re-assorted "rubbish." In the most recent formations we find the remains of great animals, with the gnawed bones of those they fed upon, under the stalagmitic droppings of the caves in which they lived, or into which they had been washed by floods. Peat bogs are also spots where man and his contemporary animals have got "laired," and as the turf preserves its prisoners in a wonderful manner they yield many surprises for the student of the world's history, though in a peat-moss geology is apt to end and the story of the human race to begin. The ordinary soil is also a repository of fossils, using the word in the sense of an organism, or anything connected with it. Hence, as in the case of resins like amber, the Kauri gum of New Zealand, or the copal of East Africa, the soil holds in store "fossils," which, though neither plants nor animals, enable us to presage something regarding the trees which exuded them, and by means of the insects, twigs, or cones (Figs. 22, 23) which were originally trapped by the sticky gums, and have now got enclosed in the hard interior of the masses, concerning the animal life of a bygone period, which has been preserved in no other way. A worm-track, or the footprint of a bird over the muddy shore of a lake, is in like manner a fossil, even though the worm or the bird has vanished. If the footprints which Robinson Crusoe detected on the sea-shore had got hardened and covered over with other layers, they would have been fossils just as much as the bones of the savages who formed them, or the flint arrow-heads or spear-points of the long-departed barbarians. The coprolites, which, as we know, are the droppings of extinct animals, are also in their way fossils, just as the cases of extinct caddis-worms are

as much proofs positive of the existence of the neuropterous insect whose larvæ made them, as if we had captured the fly itself. In like manner when we find a rock burrowed by holes which are the work of a *pholas* or a *saxicava*, there is no question of the burrows of

Fig. 22.—ANIMAL REMAINS IN AMBER.

these mollusca being fossils, though, of course, if at the bottom of the tunnel we light upon the shell of the maker, the palæontologist is in a much more satisfactory position, since he at once knows the species which made it. It is as if the historian discovers a monument like Stonehenge without an inscription or any trace of the people who made it. He can, nevertheless, deduce various facts regarding their culture, and even guess a little about their religion. If in a grave hard by he finds a skull or an arrow-head, an urn, or a necklace, he is at once provided with facts for a volume; and when an inscription, no matter how fragmentary or enigmatical, is unearthed, then the problem of who was the builder is on a fair way to be solved. This stage, however, the geologist never reaches. The best he can hope for is to get the skull or the bones of the animal; the rest of its history he must unravel by a process of palæontological reasoning.

Terrestrial animals are thus more seldom preserved intact than aquatic ones. Their bodies putrefy, so that before they can get embedded and fossilised all that usually remains, unless the animal has a shell, is its bones, dismembered, it may be, or in the condition that a carcase washed about by the tide can hardly fail to be. The deltas of rivers contain many land animals in this condition. These might have consisted of the fauna which had been swept seaward by floods, or in various other conceivable ways had met their dooms. For instance—and what has happened once might have happened before—in the great snowstorm of 1794 there were found on a part of the sands of the Solway Firth, known as the "Bed of Esk," where the tide disgorges much of what is carried into the sea by the river, "840 sheep, 9 cattle, 3 horses, 2 men, 1 woman, 45 dogs, 180 hares, besides a number of meaner animals." In Morayshire during the floods of 1829—and this example may serve for many others equally striking—the sands for miles were covered with the silted-up carcases of domestic animals, besides millions of dead hares, rabbits, and other feræ of field and wood which had been overwhelmed by the rising of the waters.

Plants.—We find a vast number of fossil plants, though it will be readily understood only a mere specimen of what existed have

Fig. 23.—VEGETABLE REMAINS IN AMBER.

been handed down to us, for if not a tithe of the old world animals are preserved in a fossil condition, how much less would the soft and often fragile flowers of a summer have survived their entombment in mud, and the inevitable maceration in water which they must have

previously undergone? Lime-encrusted seaweeds, like corallines and nullipores, would, of course, have no difficulty in being preserved. But the soft cellular species would almost certainly decay without leaving any very distinct trace behind. Still less would be the chance of the lichens and other lowly plants of the land, while the blossoms carried into the sea would, long before they reached the delta, be decomposed beyond recognition. Hence, leaves, stems, twigs, hard fruits, and the like, are best preserved, and the formations in which they are formed are usually lake-deposited, like the ferns and other plants of the shales of the Coal Measures.

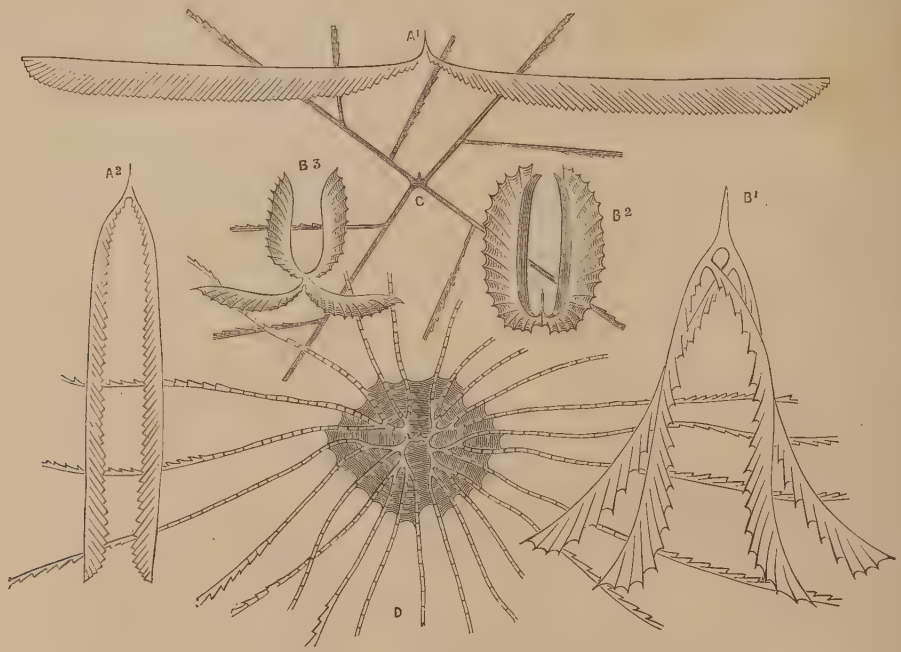
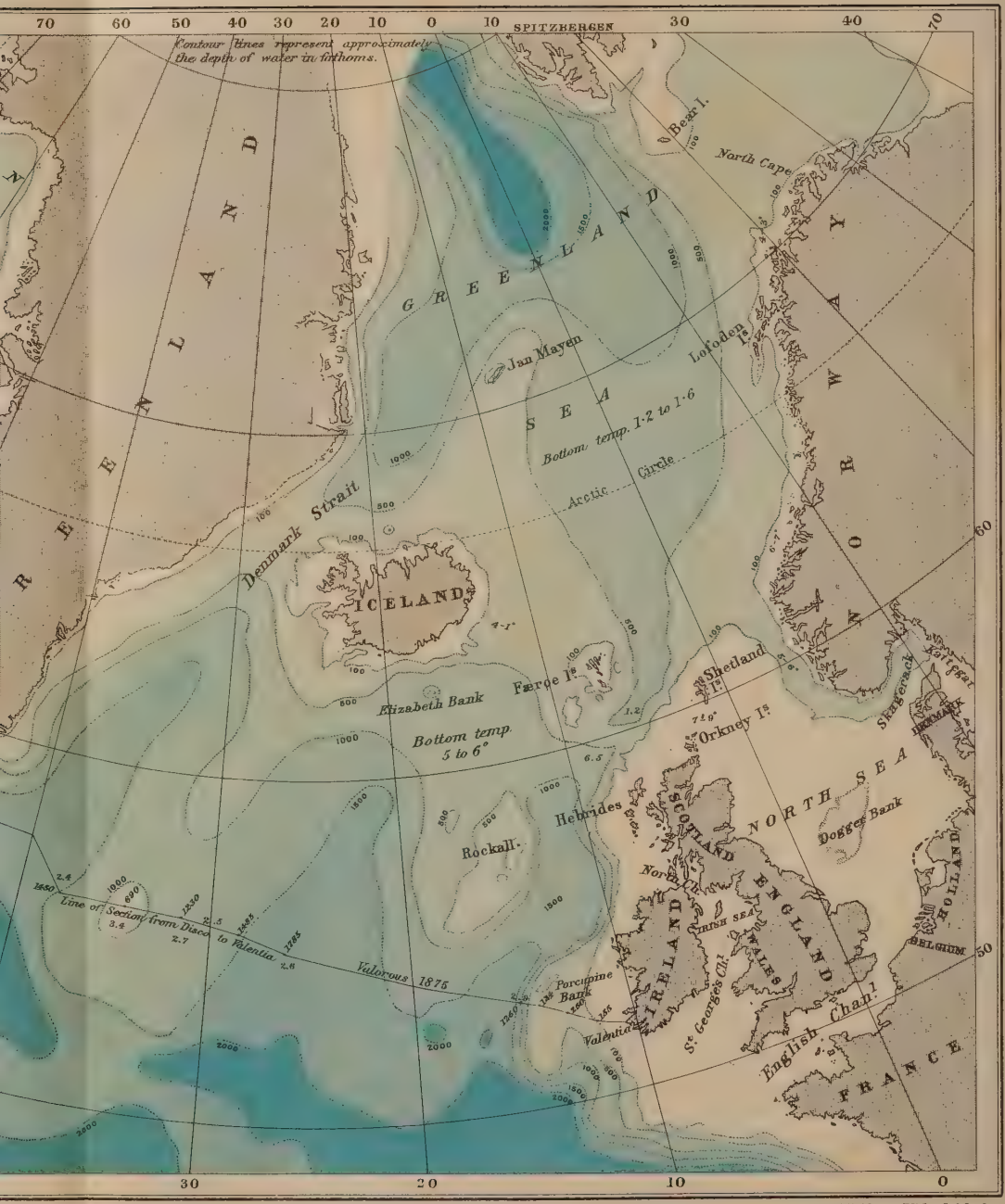


Fig. 24.—GROUP OF GRAPTOLITES (DICHOGRAPTIDÆ).

A^1, A^2, *Didymograptus:* B^1, B^2, B^3, *Tetragraptus:* C, *Temnograptus:* D, *Loganograptus.* (*After Lapworth.*)

How Fossils are Preserved. *Animals.*—The parts of mammals which are preserved, it must have been evident from the preceding remarks, are mainly their bones, teeth, and horns. Birds and reptiles are also fully represented, so far as their harder parts are concerned. The skeletons of fishes having less earthy matter—when they are not, as in the case of the sharks and their relatives, altogether cartilaginous—are less often found, the memorials of their existence in the Book of the Rocks being usually their scales, which often contain much lime, and, in the case of the garpike of the American rivers, consist of a hard cuirass, such as ensheathed so many of the Devonian species. The shells of molluscs are of course, as a rule, intact, and hence are the most satisfactory of all fossils; and the shelly mail of lobsters, crabs, etc., has been equally effectual in imparting immortality to their frail forms. The shells and spines of sea-urchins are admirably adapted for preservation; hence many of these animals are almost as easily determined in a fossil as in a recent—that is a living—condition, but their allies, the sea-cucumbers, being for the most part soft, are, like so many worms, almost unrepresented in the rocks of certain periods when, there is little doubt, they were abundant; and



ND BOTTOM TEMPERATURES (CELSIUS) OF THE NORTHERN PART OF THE ATLANTIC.

W. & A.K. Johnston, Edinburgh & London.

though insects are in many cases well-fitted for preservation in a fossil state, owing to the fact that they are for the most part denizens of the land, only a very few have been blown into the water, been embedded in hollow trees, in coal, or in resins. (Figs. 22, 23.) As for the still more lowly animals, most of them have disappeared without a trace, except when, as in the case of sponges, many delicate-shelled foraminifera, corals, and zoophytes or sea-firs, their hard exteriors enabled their outlines to be admirably preserved. (Fig. 24.)

The process of fossilisation is, however, somewhat varied. (1), The animal matter is abstracted, and particle by particle replaced by the stony material of the rock in which it is embedded. This we usually find in the oldest fossils, the degree of fossilification being in a direct ratio to the age of the beds, and more frequently in plants than in animals, though shells, sponges, and corals are often fossilised in this way, and bones are often met with in which mineral matter has so completely infiltrated them that the fragment is as solid as ever it was (indeed, more compact), only every particle of organic matter is represented by stony material. In other words, it is *petrified*.* Silica or flint is the substance which most commonly plays the leading part in the molecular change; but iron pyrites, oxides of iron, etc., may form the replacing material.

(2), By incrustation. The organic matter is surrounded by an incrustation of lime, though occasionally peroxide of iron (rust) and other substances act in an identical manner. In this case there is no fossilisation proper—which occurs only when there is displacement—for the crust is just sufficiently thick to retain the form of the substance when the organic matter has decayed, so that it is never more than an outline of the original subject, or as it were a mould of its external form. Sometimes other mineral matter infiltrates into the hollow left by the vanished organism, so that a cast is taken of the place which, under other circumstances, it might have occupied. We see this kind of petrifaction going on among plants in mineral springs (p. 13), though it is by no means uncommon in the case of animals also. (Fig. 25.)

(3), Sometimes clay or other matter—as

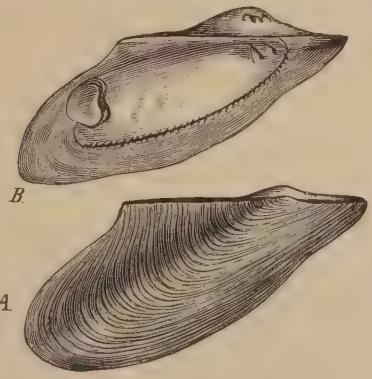


Fig. 25.—A, FOSSIL BIVALVE SHELL (*Gervillia*). B, "CAST" OF THE INTERIOR OF THE SAME, THE ACTUAL SHELL HAVING DISAPPEARED.

we see on any muddy shore—gets mechanically introduced into a shell or other hollow organism, and thus takes an accurate cast of the interior. By-and-by, if the rock in which it is embedded is porous, water may infiltrate and entirely dissolve away the original shell, so that it is represented by the cast alone. Or in other cases the shell may remain, so that there would be imminent risk — which it is vain to imagine as being always avoided—of the palæontologist describing the same animal twice over as two or three separate species, should a cast of the outside of the shell be made in addition. (Fig. 25.)

(4), By abstraction of the animal matter, leaving the mineral material unaltered (Figs. 28, 29). This form of fossil is chiefly found in very modern deposits—modern the reader will understand from the geologist's point of view. These bones—for they are generally bones—are therefore very dry and brittle, and adhere to the tongue. They are indeed so porous that if boiled in gelatine they can be restored to something like their original flexibility. In some instances even their colour has been preserved.

* Latin, *petra*, a stone; and *fio*, I become.

(5), When the fossil is preserved entire and fresh. This is extremely rare, and has happened only in the scarce instances when the carcass of the extinct woolly elephant of Siberia has been buried in the frozen soil, or having fallen into the crevasse of a glacier, has been kept intact in an iceberg. However, the frozen Alaska cliffs (in Escholtz Bay), where are numerous remains of the mammoth, have often during the heat of summer an animal odour, showing that much still undecayed organic matter is entombed there.

Fig. 26.—PART OF THE FROND OF ONE OF THE FERNS OF THE COAL MEASURES (*Sphenopteris gracilis*).

These are the principal modes in which animal fossils occur. But raindrops and ripple marks are "fossils" after their kind, and the footprints of animals form a trail from which the existence and ways of life of ancient birds and four-footed beasts can be deduced, just as the North American Indian can tell by the study of the tracks in the prairie clay how many people passed on a particular day, and even at what period of the day, what was their sex and their ages, whether or not they had pack animals, whether they travelled fast or slow, and whether they were bound on peace or war. This study of "trailing," or, as the South African hunter knows it, of "getting on the spoor" of extinct animals, has developed a sort of specialty in palæontology known as *Ichnology*,*

* Greek, *Ichnos*, a footprint.

a fossil footprint or a stone that retains the impression of the feet of an extinct bird, reptile, or mammal, being an ichnolite.

Plants.—These—of which between eight and nine thousand species† have been recorded—are found in three states. (1), The stems, flowers, leaves, and fruits, are interspersed between layers of stony matter, and are either browned or are blackened in all stages up to that of the most perfect carbonisation (Fig. 26). In this condition the plants, especially when they are ferns and fibrous leaves, look as if they were specimens pressed between the sheets of drying-paper in the botanical press, every vein and reticulation, often the most minute serrations on their edges, being preserved.

(2), Impressions of the bark, the interior of the stem or twig being either entirely empty or filled with stony matter. This we see in the common plants of the Coal Measures known as *Lepidodendron* and *Sigillaria*, the roots of which are the plants formerly described as a different genus under the name of *Stigmaria* (Fig. 27). Such fossils are,

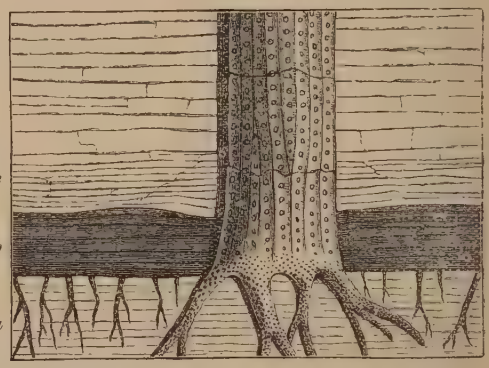


Fig. 27.—DIAGRAMMATIC SECTION OF A COAL SEAM AS SEEN IN THE FACE OF THE WORKING OF A COAL MINE.

(*a*), Underclay with roots (*Stigmaria*) passing through it; (*b*), Bed of coal; (*c*), "Roof" of the coal composed of sandstone and shales, with upright trunk of tree (*Sigillaria*) passing through it.

therefore, mere "pseudomorphs,"‡ or casts in some mineral substance.

† Ward, *Report of United States Geological Survey*, 1883–4, p. 424.

‡ Greek, *pseudes*, false; and *morphe*, form.

(3), Petrifactions in which the whole of the interior mass, vessels, and cells of the plant have been replaced with stony matter, generally silica, by being filled up, not changed into stone as the process is popularly described, so that when a piece is cut across and polished, the structure of the original wood is exhibited in its most minute details. Even the contents of the cells, to the delicate starch granules, are preserved, and in some sections the microscope exhibits the mycelium or threads of a fungus creeping through the wood, just as it does in timber affected with dry rot. In various trunks worm-holes can be seen, and from trees in the Nova Scotia coal fields, Sir William Dawson has described insects which had made them, or had taken refuge in the decaying cavities, all alike being converted into stoniness. This form of fossilisation is well known to palæophytologists,* trees many feet in length being sometimes discovered in this condition. Wood may have the cavities of its cells and vessels filled with silica or silicates, with sulphide or carbonate of iron, or with limestone, while the woody walls of the cells remain either as coaly matter or charcoal. "I have often," Sir William Dawson tells us, "seen the microscopic cells of fossil wood not only filled in this way, but presenting under a high power successive coats of deposit like the banded structure of an agate."

The process by which these various forms of fossilisation have been produced may be inferred from certain experiments undertaken many years ago. Göppert—a well-known German student of this department of palæontology—placed ferns between layers of soft clay, and then subjected the mass to a red heat, with the result that the impressions were almost identical with those of the ancient species in the grits of Silesia. Again, on putting ferns between layers of clay in a ditch six feet deep, and allowing them to lie there for a whole year, the plants were more or less browned, and might have been mistaken for fossil species in the first of the states just described. No doubt the old plants have been subjected to great wetness, and also, owing to the pressure of the superincumbent load of rock, to heat, so that these experiments represent in some degree the conditions under which they may have been fossilised many millions of years ago.

The second condition is not easily illustrated by experiment, for the mould of stone forms inside, while the bark itself is converted into coal. The plants look as if they had been flattened while soft, this appearance being seen in many species—in Calamites, for example.

In the third condition the silica, as in the similar fossilisation of animals, or the lime, or iron, or a mixture of all these, has infiltrated into the tissues. It is a process which is still in progress, the wood from old buildings under water being often semi-fossilised. Peroxide of iron infiltrates the wood which comes into contact with it; so does gypsum, or plaster-of-Paris, and there is no great difficulty in fossilising a thin slice of wood if it is soaked under pressure in water impregnated with such materials, this plan being, indeed, employed to render timber more durable. Coal can even be produced artificially.

In igneous rocks there are, as the reader has often been told, no true fossils. Their mode of formation forbids the preservation of any plants or animals which have been licked into them by the tongues of liquid lava. It may, however, happen that, when volcanic ashes fall into the sea, and form a more or less stratified bed, in the layers will be held the plants and animals of the surrounding water. These submarine tufas are, nevertheless, to all intents and purposes, sedimentary rocks, the origin of the materials of which they are formed being a secondary matter (Vol. I., p. 167). There are, however, instances in which a piece of wood or other organic remain, enclosed in a lump of clay, has been enveloped by the seething lava, and, owing to its non-conductive envelope, been preserved in a more or less perfect condition. These are, however, exceptions which do not invalidate the broad propositions laid down.

* Greek, *palaios*, ancient; and *phyton*, a plant.

CHAPTER III.

Fossils: Readings from the Rocks.

Deductions regarding the Conditions of the Earth from the Fossils of the Period—What they Tell us regarding the Climate, the Depth of the Sea, the Character of the Water, or other Conditions which prevailed at the time they were Engulfed—Cautions as to these Deductions—The Connection of Ancient and Modern Faunas—Migration—Colonies—Determination of the Relative Age of Deposits by means of Fossils—Different Strata, though containing the same Species, not necessarily Synchronous—Homotaxial Beds—Breaks in the Succession—Extinction of Species—The Dodo, the Great Auk, the Solitaire, the Rhytina, etc.—Imperfection of the Geological Record—Is there any Likelihood of the supposed Extinct Species being found Living in the Depths of the Sea or Elsewhere?—How Fossils are Deciphered and Reconstructed—Difficulties and Doubts in Palæontology—Liabilities to Error—Impossibility of dispensing with this Science—Example from the Genus *Cyprina*, of its value to the Physical Geologist, etc.

Fossils have been termed the "medals of Creation." They are so only in a certain sense. A medal has usually an inscription, which enables the reader to dispense with any speculations as to the sculpture which it describes. A fossil has no inscription; it is a medal, therefore, the character of which and the events which it commemorates must be deciphered by the unassisted light of reason. However, by careful observation of its surroundings, aided by a knowledge of the conditions of life which obtain in the living group of animals to which it belongs, we are enabled to deduce numerous tolerably safe data regarding the world to which the extinct species belonged.

Climate.—They are eloquent, for instance, of the world in which we live having undergone remarkable transformations of climate.* We find, for example, an exuberance of vegetation during the period when the coal beds were formed, which is hardly compatible with a temperate climate. In studying the older beds, analogy must mainly help us. All of their species are extinct. Many were so widely different from any living forms that their habits or the heat necessary for their existence must, to a large extent, be questions on which no positive opinion can be pronounced. However, when we disinter reef-building corals, chambered shells akin to the Nautilus, tree-ferns, and cycads (palm-like trees or shrubs of which no representative now exists in Europe), we are entitled to infer that the sea in which these animals lived, or the shore on which they grew, was more temperate than the land in which we now find their remains. If, furthermore, these tropical or semi-tropical trees can be proved to have grown on the spot, and not to have drifted (as fruits of the West Indies drift, by means of the Gulf Stream, into the Arctic Sea), this tentative belief becomes something like a positive conclusion.

When we approach nearer to our own times we find the fossils more closely approaching the living plants and animals. Accordingly our confidence is firmer in inferring that the great cowries and volutes, the palms, and other plants of the Eocene beds of Western Europe—the Thames Valley clays, for example—betoken a tropical or sub-tropical climate, since these species belong to families or genera not found in temperate latitudes. Higher up in the geological scale we come to the Miocene beds, and in them we find plants closely allied to species now characteristic of California and the Southern United States,

* In this, as in the preceding chapter, considerations of space, as well as the propriety of not entering in a treatise of this description into purely palæontological questions, have compelled us to give only the leading facts. In the introductory chapters to Alleyne Nicholson's "Manual of Palæontology" and (among other works) in Seeley's synopsis of the subject in his edition of Phillips's "Manual" (pp. 437–528) the general principles of this branch of geological science are stated with much clearness and at considerable length.

leading to the inference that Switzerland and the Vienna Basin were, in the middle of the Tertiary period, much warmer than at present. Still more remarkable is it that in Greenland we find the remains of the same vegetation, in places as far north as 70°, so luxuriant as to denote a climate widely different from that which now prevails there.* In sight of a strait choked with icebergs and ice-fields, and within a mile or two of the inland ice (Vol. I., p. 374), in a region where no vegetation is seen more luxuriant than the Arctic willow creeping along the frozen soil, or the crowberry, even less tree-like, there are beds of coal; and in Smith's Sound, close by the winter quarters of the *Discovery* in 1875-76, within less than 590 miles of the North Pole, seams even thicker were found. This betokens an entire revolution in atmospheric conditions even within comparatively recent geological periods.

On the other hand, there are fossils which tell us that a great portion of the north temperate zone, as far south as France, was at a much later date—possibly after man appeared upon the earth — under a climate comparable in rigour to that of Greenland or Spitzbergen. This we can state even more positively, for by that time the species of plants and animals were identical with those on the earth. Accordingly, when we find Arctic shells not now found in such southern seas (Fig. 28) embedded in glacial clays, such as nowadays are deposited by the muddy streams pouring out under the glaciers of the north, hard by ice-grooved rocks, and perhaps mixed up with the bones of reindeer, musk oxen, and lemmings, the inference is warranted that England in those days was not the England we know, and that the Cave men of old France had a cooler Gaul than that to which the invalid now flees to escape the northern winter. If, furthermore, we find in clays connected with the peat bogs — and probably dating from the same period—the leaves of Arctic willows,† we are quite justified in considering the conclusions arrived at strengthened by these fresh facts.

Here, however, we must interpose a word of caution. Most of the fossils from which such conclusions are drawn are the remains of marine animals, and it is therefore just possible that warm or cold currents might account for their presence so far out of their range. And, finally, it is not in every case safe to reason regarding the ancient dis-

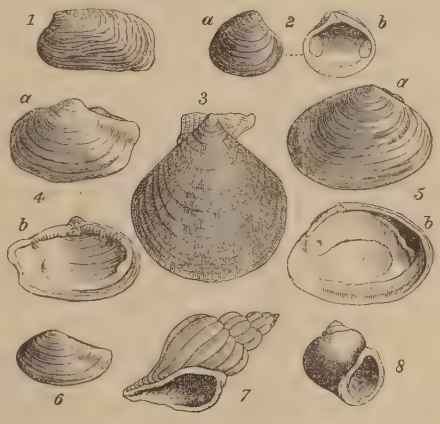


Fig. 28.—ARCTIC SHELLS FOUND IN THE SCOTTISH GLACIAL CLAYS.

1, *Saxicava rugosa*. 2, *Astarte borealis* (*a*, Exterior of valve; *b*, Interior of valve). 3, *Pecten islandicus*. 4, *Leda truncata* (*a*, Exterior of left valve; *b*, Interior of left valve). 5, *Tellina calcarea* (*a*, Exterior of left valve; *b*, Interior of left valve). 6, *Leda lanceolata*. 7, *Trophon clathratum*. 8, *Natica clausa*.

tribution of plants or animals by facts based on the range of their nearest kindred at the present day; since the geographical distribution of the modern floras and faunas is regulated by other circumstances than climate, and dates from a period so recent that it would be rash to build too weighty a superstructure on a foundation so frail as that the past distribution was solely

* These plants, a large portion of which were discovered by the writer, are described in Heer's "Flora fossilis Grönlandica" (1883); in the *Philosophical Transactions*, 1869, p. 445 (with only partial acknowledgment of the source whence the material was derived); in my paper in *Trans. Geol. Soc. Glasgow*, Vol. V., p. 54; in "Meddelelser om Grönland," Vol. V. (1883); etc.

† These are mainly *Dryas octopetala*, *Betula nana*, and *Salix polaris*. They were first discovered in Sweden by Dr. Nathorst, and afterwards in Denmark by the Etatsraad Professor Steenstrup, under whose guidance the writer collected them from the peat mosses of Zealand as early as the year 1872.

controlled by the temperature of the air which the organisms breathed, or that of the water in which they lived. These cautions are, nevertheless, little more than *obiter dicta*. They scarcely weaken the broad inferences at which we have landed. But when the bones and tusks of an elephant were first found scattered over the Siberian shores of the Polar Sea, the natural inference was that, as the two living species of elephants are denizens of the Tropics, this betokened a great change in the Siberian climate since that *Elephas primigenius* lived. Yet when, by a lucky chance, a specimen of this extinct pachyderm was thawed out of the frozen soil, these deductions were found to be entirely erroneous. The Siberian elephant was covered with wool.

Migration, no doubt, also played a part in the past, as it does in the present. An animal had its summer and its winter quarters, and might have died and been entombed in either the one or the other. Some of the great climatic changes must also have impelled the migration and prolonged residence in the south of northern species, which, when the climate altered for the better, returned to the native country of their ancestors, accompanied by some of the denizens of that in which they had so long resided. This hypothesis of migration is necessary to explain the mixture of tropical and semi-tropical species with others of later northern cast. Thus in the Tertiary deposits we find the bones of an extinct ox (*Bos primigenius*) and the great Irish elk (*Megaceros hibernicus*, Vol. I., Fig. 27), animals which disappeared in comparatively recent times, mingled with those of the hippopotamus, lion, rhinoceros (Fig. 29), and elephant, and other vanished species, which show a marked likeness to the zoology of northern Africa. As we approach our own times—though counted in years with a very long interval between—we discover that even when the geographical distribution of extinct animals is considerably different from what that of their nearest allies is in our day, certain parts of the world are now, as in former times, distinguished by characteristic forms. For example, South America was, in later Tertiary times, the land of great sloths and armadilloes, just as it is at the present day of the same kind of animals, though of species different in form and of a much smaller size. Australia was of old, as now, the home of marsupials or kangaroo-like animals, and New Zealand was, in like manner, the proper region of gigantic wingless birds, allied to those which still form such singular features in the fauna of these Antipodean islands. This shows a local persistence of type.

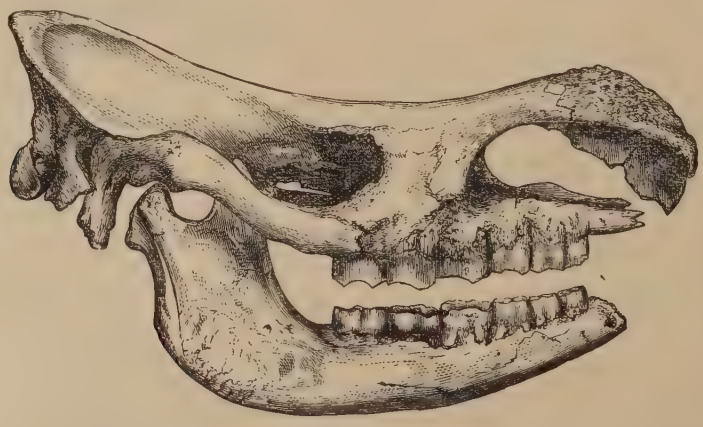


Fig. 29.—SKULL OF FOSSIL RHINOCEROS (*R. leptorhinus*, Owen), FROM THE THAMES VALLEY BRICK-EARTHS.

But when we stretch further back in geological time we find that the zoological

provinces of former periods were very different from what they are now. In the Tertiary formation of the eastern English counties, known as the Crag, we find a tapir not widely different from that of the Malay Islands, and an extinct genus of bear-like mammals (*Hyænarctos*), which we have the authority of Professor Seeley for saying resembles the same genus in the Sewalik Rocks of Northern India. Japan was at one time in the same zoological province with India, for we find that in Tertiary times the two countries were inhabited by the selfsame species of mammals, among which two kinds of extinct elephants may be noted; while the community of the Sewalik fossils with some of those in Europe and Africa tends to show either that the range of some animals was, near the close of the latest geological epoch, much wider than that of their nearest allies subsequently became, or that the migration noted existed over land-bridges which have long ago ceased to exist.*

Colonies.—This idea of migration existing among the ancient as among the modern inhabitants of the earth is at the bottom of the doctrine of "Colonies," which was advocated by the late M. Barrande, a distinguished Bohemian palæontologist. A species which once disappears never again makes its appearance, though our knowledge is still too imperfect to enable us to always say for certain that a particular animal has vanished for ever from the earth, or to fix the period when that event occurred. Indeed, from considerations which will be subsequently taken into account, this problem is never likely to be other than difficult or even insoluble. It is certain that a species may still exist, though it is not found in the rocks immediately over those in which it was last seen. For it may have betaken itself to another region, where—as we know—its remains may be disinterred from strata much newer than those from which it has been missed. The doctrine involved in these facts was, however, carried still further by M. Barrande, since he conceived the probability of a group of animals migrating from the sea-bottom of one era in the earth's history and returning to it, after the lapse of a long period, in the shape of a "colony." This view, however, is not generally accepted, the cases in which it seems to occur—and these are invariably in the older formations—being attributed not to the repetition of the same life group in the same district, but to the repetition of the same strata by inversion and contortion.†

Without taking upon ourselves to pronounce decisively in a controversy so complicated, it is clear that there can be no such thing as the abrupt ending of one ancient group of plants and animals, and the sudden beginning of another. All extinction must have been gradual: the apparent contrary is due to the imperfection of the geological record.

Physical Conditions.—Animals, and to a less extent plants also, are influenced by the depths of the sea in which they live; some species (Vol. I., p. 352) being characteristic of shallow, others of deeper water. Again, there are some species which are never found out of brackish seas, like the Baltic, or the estuaries of rivers, while others are exclusively confined to fresh-water lakes, to swamps, and to dry land. When the fossils are of species still living — as is the case to a greater or less extent in the most recent deposits — there is no difficulty in deciding as to the conditions under which they lived. But when they are extinct forms, and still more so when they are widely different from anything we know in a living condition, the problem is by no means so easily solved. Indeed, to some extent we must be guided by analogy and appearance. Many genera or whole families

* See the Coloured Map of the Depths and Bottom Temperatures of the Northern part of the Atlantic. Most of the data in this map, as well as in that of the more Southerly part of the same ocean (Vol. I.) have been taken by permission of the Council of the Royal Geographical Society from the charts illustrating Dr. Carpenter's lecture "On the Temperature of the Deep-Sea Bottom and the conditions by which it is determined" (*Proceedings of the Royal Geographical Society*, 1877, p. 289).

† Marr: *Quarterly Journal of the Geological Society*, 1880, p. 605; *Ibid.* 1882, p. 313; "Classification of Cambrian and Silurian Rocks" (1883).

Fig. 30.—IDEAL VIEW OF A LAKE VILLAGE IN THE LAIBACH BASIN, CARNIOLA.

(After a Sketch by Aug. Grosz.)

of animals are nowadays inhabitants of fresh water only, so that when we find one of that group we are reasonably justified in regarding the deposit in which it occurs as of that nature, while the belief is strengthened if all the surroundings are in keeping with the conclusion mentioned. A lake deposit, or a river deposit, or even one of a brackish character, can usually be distinguished in a similar manner, leaving out of account the fact that the shells, if fresh-water shells, are generally thinner than those of marine forms, while those of waters like the Baltic, deficient in salt, are usually small or deformed, as if the mollusc were living under conditions unfitted for its due development. On the other hand, when we come upon a deposit containing shell-fish, crustaceans (the crab and lobster family), and the bones of fishes which we know to be either wholly or for the most part of marine genealogy, we are warranted in the inference that those ancient animals did not differ from the habits of their remote descendants. Similar rules are put in practice to determine the depths at which a bed may have been deposited, our study of the fossils being in this case aided by a study of the materials which enter into the constitution of the rock. A breccia, for instance, points to a talus from cliffs, the base of which has not been much washed by the waves; a conglomerate to a gravelly beach; a coarse sandstone to a shallow shore; a finer one to deeper water; a shale to a muddy estuary, and so forth.

No nautilus, no foraminifer, no starfish, no sea-urchin, no coral, is known to inhabit fresh water. On the other hand, such genera of shells as *Planorbis*, *Limnæa*, and *Physa*, are invariably found in fresh water, while *Cerithium*, *Scrobicularia*, *Mya*, etc., are characteristic of estuaries. It is not, therefore, asking too much to believe that when we find extinct species of these families or genera, they indicate similar surroundings to have prevailed in the past, though of course the evidence is only circumstantial. A slab marked with raindrops, or ripple-marks, and still more conclusively if imprinted with the footprints of reptiles, birds, or crustacean mammals, points to a muddy shore (Fig. 31). If we find the remains of land animals intermixed with those of the sea, then we are tolerably sure that the deposit was formed close to the land, since we know that terrestrial remains are seldom found on the sea bottom far from the shore.

Fig. 31.—FOOTPRINTS OF THE CHEIROTHERIUM IN THE TRIAS AT HESSBERG, IN THE THURINGIAN FOREST.

a, Left hindfoot; *b*, Right hindfoot; *c*, Left forefoot; *d*, Right forefoot; *e*, Tracks of smaller animal.

Yet here again caution is requisite. All the sedimentary deposits are of aqueous origin, and hence in the vast number of instances, the fossils found could only have reached them through the agency of water. The mammals — the whales and other marine species excepted — must largely consist of individuals which have been drowned, and swept seaward or lakeward; and the same

conclusion is inevitable in regard to birds and flying reptiles (like the pterodactyl), unless indeed they were killed, or died, when resting on the surface. Plants also are, with few exceptions, of aqueous preservation, though of land origin. Indeed, there are very few actual terrestrial beds, the "sub-aërial" deposits being chiefly blown sand, etc., in which the remains of land species (Fig. 5) have got entombed. In the Coal Measures, however, we find true land surfaces in the shape of strata in which trees are standing upright (Fig. 27) in the soil in which they grew, the stems buried in beds of aqueous accumulation. Land shells and other terrestrial species will, however, often be found on the shore quietly silting up among marine species, owing to the fact of their having been blown over the cliffs; the same accident may mingle land and fresh-water forms together, and cases are not unknown in which, during whirlwinds or severe gales, marine shells, sea-urchins, starfishes, and the like, have been borne from the beach and dropped in upland lakes at a considerable distance from the sea.

These accidents cannot, however, in many instances lead the reader of the rock books far astray. Some beds, seemingly well fitted for the preservation of fossils, are singularly bare of organisms. Various reasons might be hazarded for this poverty of life, though when we see how some shores are rich in animals, while others are peculiarly bare, there need be little difficulty in accounting for the fact noted.

The cautious investigator of fossils is able, with some degree of accuracy, to determine the land surfaces, the lakes, and the old sea bottoms of any particular geological period. He may even presage something regarding the depth and character of the water in which the beds were laid down, and in which the entombed animals lived; and when he finds, as he does, in the clays on which the greater part of London is built, turtles and crocodiles, palms and Liquidambars, we have the materials before us from which to infer that in Eocene times the valley of the Thames was semi-tropical. Again, as we know that corals cannot live in any sea which is muddy (p. 14), it is clear that those which are found in a fossil condition must have flourished in the purest of salt water, and it is even allowable to believe that the rate of deposition of mud from the river or other agent which brought it into the sea was slow, otherwise delicate animals must have been destroyed at once, instead of being slowly done to death, as the position in which their remains are found seems to indicate. Our knowledge of the habits of the modern relatives of extinct forms enables us to gain some further information regarding the condition of life which must have obtained in ancient times. For instance, if a piece of wood bored by a teredo, or ship-worm, is found, there is no escaping the conclusion that a tree floated down a river, or in some other way reached the sea, and that after floating about half water-logged and sinking, it was attacked by the so-called worm (in reality, a bivalved mollusc), which left the proof of its former existence in the shape of a shell-lined tunnel. If a bed is altogether composed of organic remains, like the marine chalk, or the fresh-water bergmehl or tripoli (Vol. I., pp. 352, 353), the thickness of the deposit might seem to indicate that an enormous length of time must have elapsed before a deposit—due, for the most part (Vol. I., pp. 55, 74) to the dropping of minute foraminiferous shells or the equally flinty-cased diatoms to the bottom—could be accumulated. Ten thousand globigerina shells (Fig. 182, Vol. I.) will barely cover the space of a square inch, so that even after allowing for the broken fragments of the shells of bivalve mollusca, and other materials which enter into its composition, the transparent sea, in which the naked eye cannot detect a single specimen, and in which, were it milky, these delicate foraminifera could not exist, must have been raining organisms for many an age, before a yard, far less a thousand feet, of chalk could have been formed. At Bilin in Bohemia (Vol. I., p. 352) the deposit of tripoli is fourteen feet thick, this deposit being, for the most part, composed of the flinty cases of the diatoms, called *Gallionella distans*. So minute are these microscopic plants that in

a cubic inch of tripoli there are about forty-one thousand millions. At every stroke, the polisher who employs this material in his work destroys thousands of fossils. Yet it is by no means certain that these deposits took a very long period to form. The globigerina and its kindred multiply freely; and Ehrenberg, a famous German microscopist, has calculated that the diatoms are so prolific as to render it quite possible for a bed 25 square miles in area, and one and three-quarters of a foot thick, to be formed in one month from the progeny of a single individual.

Extinction of Species.—But what strikes us most markedly in reading the book of the rocks is, not so much the strange forms which are portrayed in its pages, as the fact that so many of them are extinct. Indeed, except in the very newest of formations, it is extremely rare to come upon any forms which can even approximately be considered identical with any now living on the face of the earth. All are vanished species. What is more, when we once get clear of any formation, it is the rarest possible occurrence ever again to see any of the species of fossils characteristic of it. Each period of the world's history had its own fauna and flora, that is, its own assemblage of animals and plants—and once they disappear they are gone for ever. Yet, within the historic period, we know of the extermination of only a few animals, and of no species of plants at all. Even then the extinct animals have, in every instance, met their fate at the hand of man. The dodo, a curious bird of Mauritius (Fig. 32), and the solitaires, of the Islands of Réunion and Rodriguez, were exterminated by ruthless seamen within the last two centuries. The moa of New Zealand lived long after the Maoris reached these islands. The great auk (Fig. 33) and the Labrador duck have ceased to exist, from an identical cause, within the memory of man. The Philip Island parrot is a still more recent loss, while the only mammal which can be said for certain to have been utterly destroyed from off the face of the earth is the gigantic sea-cow (*Rhytina*), of Behring Strait, though, when it was first discovered, and took the taste of the seamen who liked oily beef, its numbers were small, and seemed on the wane. These, and a few other species of less interest, form the total extinctions of which history preserves any record. But in the rocks composing the earth's crust there are the remains of thousands, which disappeared ages and ages before Man came upon the earth. Indeed, the evidence in support of his having survived many forms supposed to have been contemporary with his early life is not very decided, and may be discussed when we consider the last chapter of the geological record.

These facts of themselves compel the admission of a long lapse of time from the period of the *Eozoön* to that of Man and his contemporaries. Yet there is no ground for believing that there was, as a rule, any sudden extinction of species, any of those catastrophes which the older geologists were so fond of invoking, any cataclysm which led to the destruction of the plants and animals of the various epochs which are distinguished by special assemblages of species. They seem to have gradually dropped away in that struggle for existence the law of which is, that the fittest survives and the weakest goes to the wall, until they became circumscribed in area, and were displaced by other assemblages entirely different. This we see in almost any group of beds. The upper ones may have a different set of fossils from the bottom ones; yet the transition can be traced by the forms in the middle layers, or by those which are common to the entire thickness of strata. Sometimes we come across a vast accumulation of animal remains which, like those of the great reptiles of the Lias, might seem to invalidate this conclusion as to the slow going out of the old, and the equally slow coming in of the new forms, did we not know that even at the present day animals are often killed in numbers by causes which do not merit the name of catastrophes. For instance, a flooded river, or an immense fall of rain, has more than once destroyed marine animals unable to accommodate themselves to the unwonted influx of

fresh water. The fishes of the Jordan on the contrary, cannot survive the saltness of the Dead Sea, and an iron-impregnated spring poisoning the waters of a river has been known to kill fishes for miles from the place where it entered. After earthquakes and volcanic eruptions, the sea is sometimes covered with the dead bodies of fishes which have been destroyed by the exhalation of poisonous gases in the water (Vol. I., p. 251), and by the discharge of the products of eruption, or by the heat generated.* All this implies, not the successive annihilation and creation of the faunas and floras characteristic of different epochs, but the successive modification of pre-existing ones by a process of evolution, owing to the variability of species;

* Rupert Jones, *Geological Magazine*, Vol. IX., p. 533.

so that the modern plant and animal provinces are, like the species inhabiting them, the lineal, though much modified, descendants of those of long prior periods. There are still differences of opinion as to how far the Darwinian theory is to be accepted. But almost no one, whose opinion is worthy of quotation, holds, nowadays, that the plants and animals of the different epochs were separate creations, and not in some way genealogically connected with those which preceded them, just as they in their turn were the ancestors of the forms which succeeded them. This question will, however, be discussed at another place.

Fig. 32.—THE DODO (*Didus ineptus*), AN EXTINCT BIRD OF MAURITIUS.

Imperfection of the Geological Record.—This theory, it must be admitted, is not always capable of being supported by facts. The transitional forms cannot always be produced,

though every day more and more of the missing links are coming to the fore. But we must remember how exceedingly imperfect the geological record is, and must necessarily be. Large as the number of extinct plants and animals known to us is, it forms not then, the constant wear and tear of the world affords but an indifferent chance of those already embedded remaining undisturbed. The newer rocks are formed out of the worn-down materials of the older ones, so that it must have often happened that the fossils

Fig. 33.—THE GREAT AUK (*Alca impennis*).

a tithe of what existed, and of which no fragments have been preserved. This is evident from the conditions of fossilisation. Some were incapable of being preserved. Others, like insects and the soft-bodied molluscs, died on the land, and resolved themselves into their pristine elements, without being embedded in any strata, or leaving any record of their existence behind. Even disappeared with the hardened sediment in which they were entombed.

All this should make us cautious about jumping to precipitate conclusions founded on the absence of "missing links," or on sudden breaks from the strata containing one set of species to those holding in store another quite different. Hence, unless where one series of beds rests uncomformably upon those

below (Vol. I., p. 77), we should be chary in inferring "breaks in the succession." The intervening beds may have been denuded, and the remainder sunk with the country of which they formed a part, before those immediately on the top of them were deposited. This, of course, infers a considerable lapse of time, though not necessarily so long a period as when beds are unconformable, for in the latter case there must have been an entire change of physical conditions in the interval between the deposition of the under and upper strata. Hence, as Darwin wrote many years ago, "the noble science of Geology loses glory from the extreme imperfection of the record. The crust of the earth, with its embedded remains, must not be looked at as a well-filled museum, but as a poor collection made at haphazard and at rare intervals. The accumulation of each great fossiliferous formation will be recognised as having depended on an unusual concurrence of favourable circumstances, and the blank intervals between the successive stages as having been of vast duration. But we shall be able to gauge with some security the duration of these intervals by a comparison of the preceding and succeeding organic forms. We must be cautious in attempting to correlate as strictly contemporaneous two formations which do not include many identical species, by the general succession of the forms of life. As species are produced and exterminated by slowly acting and still existing causes and not by the miraculous acts of creation; and as the most important of all causes of organic change is one which is almost independent of altered, and perhaps suddenly altered, physical conditions—namely, the mutual relation of organism to organism, the improvement of one organism entailing the improvement or the extermination of others; it follows that the amount of organic change in the fossils of consecutive formations probably serves as a fair measure of the relative, though not actual, lapse of time. A number of species, however, keeping in a body might remain for a long period unchanged, whilst within the same period, several of the species, by migrating into new countries and coming into competition with foreign associates, might become modified; so that we must not overrate the accuracy of organic change as a measure of time." *

Add to the facts thus narrated the very important ones of many beds being still only slightly explored, while others are buried beneath those which succeeded them, and that more than one-half of the surface of the earth is covered by the sea, and the imperfect account which the rocks supply regarding the succession of life may be understood. It is quite certain, not only that a very fragmentary specimen of the old faunas and floras has been preserved, but that whole eras in the earth's history are unrepresented by any of "the medals of creation." The gap between the lowest bed of the Eocene and the highest bed of the Chalk is a case in point, though it is quite possible that in time we may discover the missing beds filled with forms intermediate between those characteristic of the Cretaceous and the Eocene periods. †

The question must often obtrude itself, whether in the progress of geological research we shall discover that some of the species thought to be extinct still live? All theory is against this idea. The type may, as in the cases quoted (p. 38), survive, but the particular species can scarcely have succeeded in holding its own. It is most improbable that any such discoveries will be made on land, though it is possible that the depths of the sea hold some surprises in store. Already, indeed, the deep-sea dredgings have brought some curious forms to light, including several belonging to genera which it was thought were extinct. At the bottom of the Atlantic, in water which is fully two degrees colder than that of the freezing-point of fresh water,

* "Origin of Species" (6th Ed.), p. 428.

† Many other cases might be cited; but those mentioned may suffice, as these gaps are rapidly filling up. For instance, the "great break" between the Palæozoic and the Mesozoic formations, which was at one time a canon with those geologists who considered that the world was built on the European plan—just as Werner imagined it to be a Saxony on a larger scale—is in America passed over lightly by a mighty series of strata following almost conformably from Cambrian to Cretaceous.

life is abundant, and by no means stunted. At the depth of 2,435 fathoms a stalked starfish, or pentacrinite, of an extinct type, associated with a sea-urchin allied to a species of the Chalk, was brought up; while some of the vitreous sponges, foraminifera, etc., have equally interesting relations.* Unless, however, it should be discovered that the half—or wholly—fabulous "sea-serpent" is one of the gigantic reptiles of the Lias—an ichthyosaurus or a plesiosaurus—it is not likely that the views already formulated will be altered by the discoveries for which we hope.

Geology thus imperfectly glides into archæology, and archæology into history. In the earlier beds of the Earth's crust—in all save the most superficial ones indeed—we find nothing except fossils by which we can gain an inkling of what went on in the world before Man became its lord. By-and-by, in the mud of old lakes and similar places, we find the remains of man and his works—rude tools, fragments of his food and playthings, and on the bottom of the lake the piles upon which he, like many savages of to-day, erected his primitive dwellings (Figs. 30, 34).† Here we have slipped into archæology. The plants and animals discovered are of the same species as those now living, though extinct in the part of the country where the Lake Dwellings, etc., are situated. But long before the probable date of these villages the present condition of affairs had begun; so that this in itself forms no boundary line between geology and archæology. It is even difficult to maintain the definition we gave of fossils—remains not buried by man (p. 29). The remains in the mud of the lakes were buried by man—that is, they dropped over the platforms on which the huts were built. Yet to all intents and purposes they are fossils, and must be studied in the same manner, since they are all that we possess to enable us to draw any inferences regarding the people who lived there before the dawn of history. All rude monuments without inscriptions come under the same head. It is only when inscriptions are found that we pass into history proper; for the inscription is the account of an actual contemporary, and relieves the student from conjecturing the use of the stone or the name or the race of the hero who sleeps beneath it.

How Fossils are Deciphered.—The reader must already have learned that fossils are rarely found in an unbroken condition and that they require much piecing together. It is, indeed, seldom that the entire skeleton of an animal, or all the preservable portions of its body, are entombed in the rock at any one place. A tooth is here, a vertebra—or "joint"—of the backbone there, or a limb at another place. Teeth and spines are often the only fragments of fish which remain for the palæontologist to study, while we have seen that leaves, fruits, and stems, are the portions of plants embedded in the rocks most frequently.

Hence the process of deciphering is often puzzling, and never so easy, except in the case of shells, as when we have fresh specimens before us. However, as we know that all plants and animals are framed on particular plans, we can usually reproduce from analogy the missing parts, though, of course, the general, not the exact or specific, features are all that the naturalist can thus tentatively build up. His dependence is on what is known as correlation of structure. For instance, as plants which have netted leaves have also the wood of their stems (Fig. 35) arranged in concentric circles (like our ordinary forest trees), we know that if even a scrap of a leaf is discovered the tree must have been a member of the great division called dicotyledons, that is, the young plant in the seed has two cotyledons or lobes, this being another form of structure which accompanies the two already noted. Again, if the leaf is veined in parallel or converging ribs, it belonged to the monocotyledons—plants with one seed lobe—and had its wood arranged not in concentric circles, but in the manner exhibited by a palm-tree trunk (Fig. 36.). Ferns, on the other hand, have forked venation, and the wood of their stems arranged in an entirely different fashion from the other two great plant groups (Fig. 37).

* Seeley, *op. cit.*; pp. 443, 452.

† "The Peoples of the World," Vol. V., pp. 127–133.

Fig. 34.—REMAINS OF A LAKE VILLAGE OF THE BRONZE AGE, NEAR MÖRIGEN ON THE LAKE OF BIENNE, SWITZERLAND, EXPOSED IN CONSEQUENCE OF THE SHOALING OF THE LAKE IN OCTOBER, 1874. (*From a Photograph.*)

A number of other correlated peculiarities of structure might be noted: but these may suffice to illustrate what is meant by the

Fig. 35.—SECTION OF STEM OF FIR (TYPE OF EXOGENOUS GROWTH).

term. Accordingly, even a broken bit of fruit, or wood, or leaf, will tell much about the plant to which it belonged.

In the animal kingdom a similar law

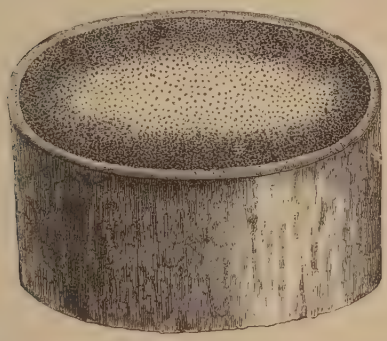


Fig. 36.—SECTION OF STEM OF PALM (TYPE OF ENDOGENOUS GROWTH).

applies. Certain forms of teeth are, for example, characteristic of certain families of animals, or denote whether they were flesh-, fruit-, or insect-eaters, and in like manner particular groups of mammals can at once be picked out by the form of their skeletons or of particular bones forming those skeletons. A vertebra, concave at each end, proves it to

have been that of a fish, and a tail unequally lobed, as the tails of most of the ancient fishes are, denotes that, by the correlation of structure, their skeletons were cartilaginous,

Fig. 37.—SECTION OF TREE FERN (TYPE OF ACROGENOUS GROWTH).

and their general character was that of the shark family (Figs. 38, 39). If we find the internal bone of a cuttlefish, we know that it must have had an ink bag, and possessed all the other structural peculiarities

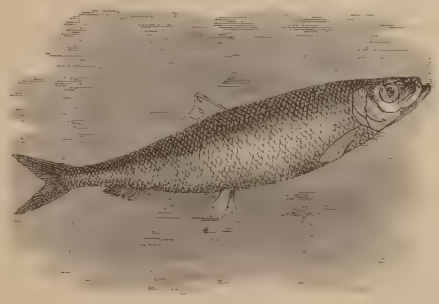


Fig. 38.—HERRING (TYPE OF FISHES WITH HOMOCERCAL OR EQUALLY-LOBED TAILS).

of the cuttlefish family. Furthermore, a skeleton necessarily implies muscles attached to it, and the places of the attachment of these muscles, as well as their size, can be noted by the slightly or heavily marked lines, or elevations on the bones. In this way the missing bones, or pieces of bone, are tentatively supplied, and the built-up skeleton clothed

with flesh. The size and outline of the animal is thus obtained. Now it is certain that every mammal—and for the present we are only speaking of suck-giving quadrupeds—

Fig. 39.—SHARK (TYPE OF FISHES WITH HETEROCERCAL OR UNEQUALLY-LOBED TAILS).

had in the past, as in the present day, a skin, and it is not risking too much to affirm that a carnivorous or flesh-eating species was covered with hair, while one, allied to the sheep family, was clothed with wool or something akin to it. On the latter point, however, with the woolly elephant in our memories (p. 38), it is well not to be too rash. Horns are always indicated by the bony protuberances which form their base, and the length of the tail is, of course, indicated by the length of the "caudal vertebræ," that is, of the continuation of the backbone. Hence, proceeding carefully from the known to the less known, an extinct animal has been built up from little more than a tooth, or a few bones, with such accuracy, that when the complete skeleton has been found in the course of further explorations there was not a great deal to alter in the more or less ideal reconstruction. It will, naturally, now and then happen that two or three separate species are founded on as many detached fragments of the same skeleton. But by-and-by, when the complete skeleton is found with all the bones in position, these errors are corrected. For example, the foot-prints of the animal which has been provisionally termed Cheirotherium (Fig. 31), so plentiful in the red beds of the Trias, are now believed to be those of a species of Labyrinthodon, a huge frog-like amphibian with a head more than three feet in length by two in breadth.

Palæontology has thus, like every other department of knowledge, its difficulties and doubts, its causes of error which are hard to avoid, its problems at the solution of which in the present state of our information we can do little more than gravely guess. Yet it is vain to dispense with the science which deals with fossils. To the physical geologist they are almost as important as to the student who concerns himself with the classification of beds and the origin and sequence of life. For if now and then the data derivable from them have been used "with too much dogmatism and too little learning," every induction of palæontology, as Professor Seeley aptly points out, is based upon evidence from the purely physical conditions of strata. Thus, the genus of bivalved shells called *Cyprina*—and it is only one out of many examples—is met with successively in the Lower Greensand, in the Thanet Sands, and in the London Clay, in each instance represented by different species. Then we come upon it in the Crag, which is also a sandy deposit, and finally find it living in our own seas as a coast species in no great depth of water, so that we are justified in concluding, in the face of any evidence to the contrary, that this was always the mode of life adopted by the different species of this long-lived genus. Some types became early extinct. Others persisted from age to age, in ever-dwindling numbers, until genera which had numerous representatives in ancient days are now reduced to one or two species. *Nautilus* is an example: it ranges through almost every formation, while *Patella* (limpets), *Dentalium* (tooth shells), *Trochus, Natica, Cardium* (cockles), *Pecten* (scallops), etc., are genera which first began to appear in early Palæozoic times.

CHAPTER IV.

The Palæozoic Rocks: The Archæan System.

Geological Time very different from Time as reckoned by the ordinary Historian—Attempts made to calculate the Age of the Sedimentary Formations by Croll, Thomson, Tait, and others—Difficulties of the Question—The Short Period assigned by these Physicists incompatible with the Darwinian Theory—The Age of Rocks therefore to a large extent Comparative and Relative—How this is arrived at—Geological Systems—How Classified and Named—Horizons—Caution requisite in Correlating widely separated Formations—The Classification usually Adopted—Palæozoic Epoch—The Azoic, Archæan, Eozoic, Hypozoic or Pre-Cambrian Rocks—Their Distribution and Characteristics—The Laurentian and Huronian Rocks—The Eozoön canadense—Its Doubtful Character—Its Range and Characteristics—Its Modern Representatives or nearest Allies—The so-called Species of Eozoön found in Europe—The Beds of Iron and the Veins of Graphite as indicating Plant-life in the Archæan Rocks—The Great Beds of Limestone equally indicative of Animal Life—The Physical Geography of the World at the Period when the Rocks containing these Remains were laid down, etc.

The merest tyro in geological science must be well aware that when the geologist talks of time, he does not measure the lapse of years by any means such as those which are at the disposal of the historian. He deals in intervals so enormous, that it is difficult for the mind trained in the puny periods of the chronicles of mankind to quite grasp their immensity. To him a few millions of years are not a great stretch; a few thousands are represented by a trifling addition to the mud of a delta, or a barely appreciable diminution of the altitude of a watershed. The geological clock keeps time rather roughly. Nevertheless, an attempt has been made to estimate the period which must have elapsed since the first of the sedimentary formations was laid down. The calculations with this end in view are based upon the consideration of some of the many facts which we have discussed in previous chapters. For instance, those who pin their faith to the changes of the past having been identical in kind with those at present in operation, reckon that if a river wears down a continent at a given rate to-day, the sediment of which the strata are composed must have taken so many millions of years to accumulate. This mode of measurement, however, takes for granted that the rivers, and seas, and glaciers, and rainfalls, and other geological agents, were never at any period of the world's history more active in their work of wearing down and building up than their successors, as we know them, are. Of this postulate we cannot make sure. Hence, a possible fundamental error is at once introduced into our calculations. This is the lithologist's way of trying to get at the age of the Earth, and the results are, as might be expected, somewhat discordant, Dr. Croll considering that the antiquity of the oldest sedimentary rocks—those which will be considered in the next chapter—is not less than 60,000,000 years; while Dr. Haughton, reasoning from much the same data, fixes the minimum duration of what may be called strata-making time at 200,000,000 years.*

The astronomers are not much more precise. Note, for instance, the calculations of Sir William Thomson. Taking for granted—and the assumption may be admitted—that the Globe has been continually cooling by its internal heat radiating into space without sensibly elevating the temperature of the upper crust, a time must have been when the now "solid earth" was a liquid sphere. This period Thomson has fixed at not less than 20,000,000 and not more than 400,000,000 years ago. He is, however, inclined to lean to the lower rather than to the higher estimate, and in any case to state the age of the

* Croll: "Climate and Time," pp. 311–359; Haughton: "Six Lectures on Physical Geography," p. 94.

Earth—that is, the time when a crust began to form upon it and sedimentary strata could commence to accumulate—at something like 100,000,000 years.

The arguments from tidal retardation, and from the origin and age of the sun's heat, are more recondite, though not more satisfactory. If the Globe had become solid more than 100,000,000 years ago, Thomson contends that the centrifugal force caused by the more rapid rotation, due to the absence of friction from the tide-wave, must have given it a greater polar flattening than it actually possesses. As for the argument that as the sun has been cooling at a uniform rate, its age cannot be more than from ten to twenty millions of years (with ten millions still to go upon), this is generally regarded as too vague to be accepted as the basis for any safe conclusions regarding the age of the Earth.*

Against these ingenious arguments have been opposed the fact that there are no means of determining the rate at which radiation has taken place in the past, since at present the atmosphere checks radiation in proportion to the quantity of moisture it contains. Hence, though there has been unquestionably a loss of temperature, "our knowledge is not yet sufficient to fix the rate of it, still less the period when the Globe became habitable, and when it shall cease to be." This is a mere speculative question to the solution of which the organic world furnishes no guide. On the contrary, what inklings it affords tend in a direction altogether contrary to that indicated by the researches of Thomson and Tait, the latter of whom does not hesitate to affirm that the "possible period which can be allowed to geologists is something less than ten millions of years." † If the Darwinian theory is correct, ten millions of years would go a very little way in allowing for the immense period which must have elapsed in order to admit of those endless modifications of forms, the assumption on which this now widely received view is based. The oldest of fossil forms—with one doubtful exception—the trilobites, the Nautilus, Lingula, &c., are so comparatively highly organised that it is impossible, if Mr. Darwin's doctrines are to be accepted, to regard them as the earliest forms which appeared upon the globe (Fig. 40). They were not the progenitors of all that follow: they were the successors of species which have left no trace. Hence, if the Darwinian theory is true, it is indisputable that long periods must have elapsed before the lowest Cambrian beds were deposited, periods as long as, or probably far longer than, the whole interval from the Cambrian age to the present day; and that during those vast periods the world swarmed with living creatures. But if Sir William Thomson, and the physicists who follow him, have not miscalculated, it is doubtful whether the Earth, in a fit state for the habitation of living creatures, has lasted long enough, unless, indeed, the world at a very early period was subjected to more rapid and violent alterations in its physical conditions than those now occurring, and that "such changes tended to induce changes at a corresponding rate in the organisms which then existed," ‡ a suggestion for which there does not appear to be any sound basis.

The Age of Rocks.

It therefore follows, from what has been said, that there is no safe guide by which the actual age of the world—of the sedimentary formations—or of any particular bed can be fixed. Geological time must, to a large extent, be relative. Mineral structure, superposition, fossils, and the fact of one rock including in its composition fragments of others (for as one bed is made out of the

* Thomson, *Trans. Geological Soc., Glasgow*, Vol. III., p. 16; Kirkwood, *Proceedings of the American Philosophical Society*, Sept., 1879. Professor Simon Newcomb is even more positive, as he affirms that "on the only hypothesis science will now allow us to make respecting the source of the solar heat" (the gravitation hypothesis of Helmholtz), "the Earth was twenty millions of years ago enveloped in the fiery atmosphere of the sun."

† Tait: Lectures on "Recent Advances in Physical Science" (1876), p. 167.

‡ Darwin: "Origin of Species," p. 286.

refuse of pre-existing ones, the contained fragments show which of the two rocks is the older), are the only trustworthy means at our disposal when we attempt to ascertain the age of beds even in this comparatively loose fashion.

The age of volcanic rocks is even less easily tested, but unquestionably they were erupted at different periods, and have peculiarities corresponding to their various dates, though no doubt the products of eruption differed in early epochs of the world's history, just as at the present day we find unlikeness when we compare the lavas, say of the Andes and of Iceland, which pristine differences have been increased by the slow changes which

Fig. 40.—FOSSILS OF THE TRIASSIC SYSTEM OF THE ALPS.

1, Posidonomya clarai; 2, Naticella costata; 3, Retzia trigonella; 4, Spiriferina mentzeli; 5, Ammonites (Ptychites) studeri; 6, Ceratites (Tirolites) cassianus; 7, Ammonites (Trachyceras) Aon; 8, Halobia (Daonella) rugosa; 9, Cardita crenata; 10, Myophoria kefersteini; 11, Cidaris dorsata; 12, Chemnitzia gradata; 13, Ammonites (Arcestes) galeatus; 14, Ammonites (Arcestes) tornatus; 15, Ammonites (Pinacoceras) metternichi; 16, Ammonites (Sageceras) haidingeri; 17, Ammonites (Phylloceras) neojurensis; 18, Ammonites (Bucephalus or Tropites) subbullatus; 19, Nautilus sauperi; 20, Orthoceras salinarium; 21, Aulacoceras alveclare; 22, Monotis salinaria; 23, Dadocrinus gracilis; 24, Gyroporella annulata; 25, Pterophyllum jaegeri; 26, Pterophyllum haidingeri; 27, Alethopteris meriani.

Time has wrought. We are, nevertheless, tolerably safe in saying when an igneous rock rests on an aqueous one, that the latter is the older of the two, and it is quite as warrantable to affirm that when a volcanic dyke bursts through a series of sedimentary strata, the intrusive rock is newer than those through which it has burst. This rule can, nevertheless, only apply to the beds actually pierced, since the discharge of lava may not reach the surface, and the strata immediately superimposed may be newer and entirely unaffected.

It also sometimes happens that the lava sheet interstratifies (Vol. I., pp. 101-2) with the aqueous beds, by the discharge which formed the dyke pouring out on the surface and getting afterwards overlaid by beds subsequently formed, or by forcing its way outward in a lateral direction. In the case just mentioned the rocks on either side are seen to be metamorphosed, while in the former instance there will be no trace of alteration; so that egregious mistakes are barely possible.

As we have already noted, it is quite possible for showers of ashes, etc., to fall from a volcano into a lake or sea, and form beds at the bottom, in which the shelly and other animals living there would get embedded (Vol. I., p. 167). In such a case these fossils would at once tell the age of the tufa.

The test of included fragments is also applicable to volcanic rocks, the lava discharge having licked into its mass fragments of sedimentary beds. Sometimes, also, we come across a conglomerate composed of trap pebbles, associated with pieces of a fossiliferous rock, so that after the age of the fossiliferous fragments has been determined, that of the massive trap, from which the igneous ones come, can be approximately fixed.

Lastly, mineral structure will sometimes enable us to ascertain the age of a particular igneous rock, lavas from any particular eruption or place being often homogeneous for long distances—that, for example, of Skaptar Jökull in 1783 keeping its character in a flow of ninety miles, while the molten rivers from Mauna Loa course for many leagues (Vol. I., p. 150). Accordingly, if streams such as these were in course of time broken up by denudation into mere isolated patches, it would be quite easy to detect their isochronous character. It will sometimes happen (Vol. I., p. 146) that successive eruptions partake of an identical mineralogical character. But, on the other hand, it is not unfrequently the fact that owing to the eruptive agent tapping some fresh reservoir, the lavas discharged within a few days of each are totally unlike. Here, naturally, the test mentioned entirely fails.

Geological Systems, etc.

Relying on the various methods described, geologists have arranged the various beds in the Earth's crust in a regular chronological order, though we may again repeat, there is no place on the surface of the globe where the whole series is found, one above the other, in the sequence in which we shall examine them. This arrangement is one which depends mainly on the study of the contained fossils, though, as we have seen, it does not necessarily follow that "homotaxial" beds—that is, beds widely separated, but containing the same species of plants and animals—are of the same age (p. 39). Nor must we jump to the conclusion that because a series of beds, say in India and in Europe, contain different fossils they are not contemporary. In our day there are beds forming at the same moment in the delta of the Po, the Mississippi, the Nile, and the Ganges, which must necessarily hold in store the remains of entirely different species of plants and animals, since different regions of the world are characterised by different assemblages of animal and vegetable life—in other words, by different floras and faunas. We have no reason to affirm that the same elementary law, regarding the distribution of the world's inhabitants, did not hold true in the remotest ages of the world's history. Still, the fossils of any particular epoch have a certain *facies* or general appearance, so that we have rarely any difficulty in pronouncing them as belonging to the same era.

The plants and animals of the Carboniferous period have, for example, such a general likeness, even when the species are different at different places, that there is seldom any error in correlating the beds belonging to that particular age of the world's history. In this way we divide off the crust of the Earth into great epochs. These *epochs* are again subdivided into *systems*, each system being made up of related *formations*, while in every formation there is generally a number of *groups*, of which the connecting link is the presence of a particular species or genus, or a number of species or genera of fossils, common to all of them. Finally, each of these groups contains several zones or *horizons*, each of which for convenience' sake goes by the name of the fossil most predominant in it or most typical of the zone, which may be a single bed or a number of beds.

As might be expected, geologists are not at one in agreeing what systems should be included in particular epochs, or where one system ends and another begins, especially when the transition from the one to the other is not abrupt but gradual. These differences, however, are not of any great importance, and are founded more on the various views which are held regarding the relative value of particular fossils for the purposes of classification than on any fundamental principles affecting the doctrines already enunciated. For instance, one writer thinks proper to put the Archæan rocks into an epoch by themselves, while another ranks them, as we shall, "without prejudice," merely for convenience' sake, in the Palæozoic division. Again, there are many geologists who put the Pleistocene among the Tertiary beds, while others rank them among the Quaternary, or Anthropozoic formations. The number of systems also forms a theme regarding which a difference of opinion may be entertained, while the American, or Indian, or Australian beds, which represent others of the same geological age in England, or Germany, or Spitzbergen, cannot always be decided with mathematical accuracy. However, for all practical purposes the brief sketch of the beds forming the Earth's crust, which will form the subject of the next few chapters, may be arranged as follows, beginning from the bottom and going upwards :—

(1) The *Primary* or *Palæozoic* epoch, containing the *Archæan*, *Cambrian*, *Silurian*, *Devonian* (Old Red Sandstone), *Carboniferous*, and *Permian* systems.

(2) The *Secondary* or *Mesozoic* epoch, containing the *Triassic*, *Jurassic*, and *Cretaceous* systems.

(3) The *Tertiary* or *Cainozoic* system, containing the *Eocene*, *Miocene*, *Pliocene*, and *Pleistocene* ; and, finally,

(4) The *Quaternary*, *Post-Tertiary*, or *Anthropozoic* epoch, which may be reserved for the recent beds in which appear traces of Man and his works, or which are forming at the present day, though in reality it is more than doubtful whether the Pleistocene should not also be included in this group. In any case, the transition from that system is so gradual as to be almost imperceptible, while it is, perhaps, unnecessary to remark that the relative importance of the Quaternary epoch is by no means comparable with that of the infinitely older ones preceding it.

Nomenclature of the Formations.—The names applied to these systems, primary divisions, formations, groups, or stages, are not based on any scientific principles. The earlier ones, like the Oolite, Chalk, and Millstone Grit, smack of a period when mineralogy and not palæontology was the chief reliance of the geologist. Others like the Wenlock Limestone, the Tremadoc Slates, the London Clay, the Oxford Clay, the Bradford Clay, or the Purbeck and Portland Beds, are named after the places in which they are well developed, or in which they were first systematically studied. Many of the great divisions are named after this fashion, the Cambrian from its typical development being in Cambria or Wales, the Silurian owing to its principal stretch being in the country occupied by the ancient British tribe of the Silures, the Jurassic from the Jura Mountains, where it is well displayed, the Permian from Perm in Russia, or the Devonian from the fact

that it was first studied in Devon, where the most extensive beds in England exist. On the other hand, the Cornbrash, the Crag, the Lias, the Marlstone, and the Gault, recall the early labours of the father of British geology, who earned the honourable title of "Stratum" Smith from his well-spent enthusiasm in studying and classifying the English beds, to many of which he applied local names like the above. The Old and the New Sandstone, the Eocene, Miocene, Pliocene, Pleistocene, and so forth, are names of a later date. They are indeed landmarks in the progress of geology intimating that by the time they were applied, Palæontology had begun to take a prominent part in a science in which hitherto Lithology had had the principal part. For these terms express a decisive opinion as to the relative age of the groups to which they are applied, while the Lingula Beds and the Nummulite and Fusulina Limestones are specimens of the names attached to particular deposits characterised by an abundance of some special fossil.

It may, nevertheless, be advisable to warn the tyro that some of these have, in progress of time, become less applicable than at the period when they were first used. It does not, for example, follow that all the Old Red Sandstone system is composed of red sandstone or indeed of any kind of sandstone, the flags of Caithness and Orkney in which some of the most remarkable of its fossils have been found, being a peculiarly bluish-dark slate or shale, extensively employed for the pavement of footpaths. Again, it is by no means the case that all the formations comprised under the head of Cretaceous contain, as the name might seem to signify,* any form of chalk. On the contrary, some of the most extensive members of this system consist of sandstones and shales, and in America and the Arctic regions coal beds, without any trace of chalk, belong to the Cretaceous period. The Carboniferous or Coal-bearing system, though in Britain distinguished by vast beds of coal, is not throughout the whole world so characterised. Even in Britain extensive deposits of limestone belong to it, and these in their turn give place to the shale and sandstone found in connection with the Coal Measures of the North, though it does not follow that when a bed of coal is pierced the Carboniferous system has necessarily been reached. On the contrary, this substance is found, in almost every period of the world's history, wherever there was vegetation sufficient to form it, though it is most markedly developed in the system to which it gives the name just discussed. All that is meant by such designations is that the rocks to which they are applied represent a particular era in the world's history, and are characterised by having much the same fossils in common.

In like manner when we speak of the Wealden, we do not mean that the particular strata or fossils are confined to the English district known as the Weald, or that there are no Necomian beds in any other locality than Neuchâtel (the Necomia of the Romans), or Cambrian out of Wales, or Devonian out of Devonshire. These names are geographical, but they do not express geographical but geological and chronological facts.

This confusion is to some extent due to the accident of systematic geology taking its rise and development in Great Britain, and particularly in England. Hence, the early geologists gave English names to formations which were at that time only known in England. Some of these have been retained. Indeed, so far as the great divisions are concerned, they are practically the same in every country. In Germany, however—from which, owing to the influence of Werner and his pupils, some of our early names were derived—many of the systems have received other designations in no way better, since they also are derived from local beds, though as many such are developed on the Continent which are not seen in Britain or America, this result was inevitable. The same remarks apply more or less to other countries. In most cases, however, the correlation of the beds thus variously named has led to the avoidance of confusion, and to the gradual

* Latin, *Creta*, chalk.

community of names. By-and-by some of these provisional names will be dropped, and as is now the case in zoology, botany, and mineralogy, one common designation will be agreed upon, though this is not possible until every portion of the world has been better explored.

Fig. 41.—IDEAL LANDSCAPE IN THE CAMBRO-SILURIAN PERIOD.

Archæan System.

The *Primary* or *Palæozoic* * rocks comprise an extensive range of fossiliferous rocks of varied lithological texture, and containing animals and plants in varied quantities and of all degrees of development. No backboned animals, however, are found in the lower systems, and in the upper or newer the species are solely fishes and amphibia, coupled with an enormous development of the plant life, to which we owe the Coal Measures. Sandstones and shales predominate, and from their alternation with conglomerate and other rocks composed of shore remains, it is inferred that when the rocks of which the Palæozoic systems are composed were laid down, the world must have been comparatively tranquil, and the sea bottoms on which they were deposited slowly subsiding. The fossils, indeed, indicate as much; some of them, like the graptolites (p. 32), are extremely delicate, and though the beds in which they are contained have in many instances been metamorphosed in various degrees, they have still preserved their forms; albeit, many other species which must have existed contemporaneously with them have disappeared.

But at the base of this great Palæozoic series there is an extensive system of rocks, the nature and origin of which are capable of even more extended discussion than they

* Greek, *Palaios*, ancient; and *zoon*, an animal.

have as yet received. By some writers they have been termed the *Azoic*,* or lifeless. But as it is more than doubtful whether this term is justified, it is better to employ the title of *Archæan*,† or ancient. That they are of incalculable antiquity admits of no possible dispute. Their very stratification is in many cases by no means clear. Some of them—the majority, indeed—are composed of gneisses and schists, crystalline and foliated in the manner already described (Vol. I., p. 114), as seen in rocks which have been subjected to metamorphism. Others are quartzites, conglomerates, and limestones, which though also, as all of them have been, greatly altered by the changes which Time and the metamorphic forces have wrought in them, are more evidently of sedimentary origin; while a third series of these Archæan beds may be regarded as of volcanic origin. This, indeed, is only what might have been expected, considering their close relations to the plutonic rocks on which they lie. So altered are these formations that it is still a dispute whether anything like a recognisable sequence of their beds can be traced. Some geologists have tried to make this out. Others, like Professor Lapworth,‡ are equally firm of belief that the planes of foliation which have been described in gneisses and schists (Vol. I., p. 113) are not planes of deposition but planes of shearage and cleavage. It is, therefore, idle to apply to these extremely ancient rocks any of those rules by which the stratification of the more recent ones have been made out, far less to apply these rules with the object of determining the relative ages of the much metamorphosed beds which everywhere characterise the Archæan system. Sir William Dawson will even claim that they have been formed under circumstances which were not paralleled "unless exceptionally in later times" (Vol. I., p. 115)—a view which for the present it may be safer not to accept.

Yet the Archæan rocks are of very wide distribution, albeit, it is not in many localities that by denudation, or otherwise, they rise from beneath those of Cambrian age. In Lewis and other parts of the outer Hebrides, and the western parts of Ross-shire and Sutherlandshire, they are well developed, and in Wales the Cambrian Rocks all rest on an Archæan foundation. They are found, among other localities, in Great Britain, though this has been doubted, in Donegal in the north-west of Ireland, but it is probable that the metamorphosed beds of the Wrekin District, the Malvern Hills, and Charnwood Forest are of a rather later date than the rocks now under description.§ The system is, however, well marked in the Ural Mountains, in the Carpathians, and in the uplands of Bavaria, Saxony, and Bohemia, as well as in the Pyrenees, the Taunus, the Central Alps, in the Sierra Nevada of Spain, and other localities. Indeed, the greater part of the Scandinavian Peninsula is Archæan, and the rocks against which the Atlantic dashes on the coasts of Brittany and Normandy are gneisses believed to belong to this period of the world's history. In Canada they extend from Labrador to Lake Huron, and then in a north-westerly direction to the confines of the Polar Basin, many portions of which are dotted by islands of these rocks. Hudson's Bay and Straits show Archæan beds, and in Northern New York, beds of the lower series are very prominent, rising as they do into the rugged heights of the Adirondacks, and in the elevated country to the south of Lake Superior, while in Asia they appear in India, are extensively developed in China, and spread over most of New Zealand.

There is, nevertheless, much doubt as to the correlation of some of the rocks classed

* Greek, *a*, without; and *zoe*, life.

† Greek, *Archaios*, ancient.

‡ *Geological Magazine*, 1885, p. 106.

§ These technical questions are fully threshed out in papers by Allport, Bonney, and Callaway, in *Quarterly Journal of the Geological Society*, Vol. XXXIII., p. 449, Vol. XXXVIII., p. 119, and Vol. XLI., p. 221, and, in addition to others, by Mr. Etheridge in his edition of Phillips's "Manual" (1885), pp. 16–28, and by Mr. Jukes-Browne in his "Historical Geology" (1886), pp. 44–56, to which the reader is referred for an admirable account of the stratification of the British rocks in much fuller detail than can be given in our pages.

as Archæan, and the chances are that many beds of widely different ages have been bracketed under this general head, the absence of fossils making any attempts at their chronology extremely difficult. Two broad groups have, however, been traced out in the system. The Lower or Old Gneiss formation is best known by the name which it bears in Canada of *Laurentian*, from being markedly developed in the Laurentide Mountains, and consists mainly of crystalline rocks, quartzite, crystalline limestone, and hornblende schist. The Upper, which in Central Europe seems to be a gradual continuation of the Lower one without any unconformable break, is in Canada known as the *Huronian*.* It consists in that country of strata from 10,000 to 20,000 feet thick, lying unconformably above the Laurentian. But in Central Europe, the Crystalline Schist Formation, as it is called, is by no means so thick, its strata being mainly various schists, such as those distinguished by the presence of mica, talc, and chloritic minerals, by phyllites, and by an occasional bed of conglomerate, penetrated in places by dykes, veins, and other intrusions of granite and igneous rocks of that class (Vol. I., pp. 188, 189); while in the Huronian beds we find diabase, melaphyre, gabbro, and other plutonic flows so interbedded that no doubt can exist as to their having been contemporaneous with the strata. (See the geological maps of the British Islands [Vol. I.] and of Central Europe.)

Origin.—How these rocks were formed is a question which admits of the widest contrariety of opinion. The preponderance of belief is, however, in favour of their having been the first beds deposited after the molten globe became cool enough for the condensation of watery vapour, and consequently for the formation of seas, lakes, and rivers. Sir William Dawson's opinion has already been quoted. Mr. Marr, on the other hand, inclines to regard them as for the most part of volcanic origin, and not ordinary marine sediments, and believes that during the Archæan age the young world was a scene of violent and almost continuous volcanic activity, followed near its close by equally violent denudation and erosion, to which, among other results, we owe the Cambrian beds which succeeded the Archæan. It is, however, quite certain that all of the Archæan rocks were powerfully metamorphosed, and then during the Cambrian period little of the world which had existed in the previous age was above the surface of the sea, except here and there a lofty peak.

Fossils.—These doubts are all due to the absence of life in the Archæan beds. Many palæontologists are of opinion that at that era plants and animals did not exist on the earth. On the other hand, in addition to the iron ores which give the Erzgebirge their name, the great masses of iron ore which render the Laurentian of Canada so notable from an economic point of view,† may be due to the action of vegetable life (Vol. I., p. 67). In the Laurentian rocks are also found considerable quantities ‡ of graphite, the "black lead" of drawing pencils, which is in all likelihood nothing more than coal highly metamorphosed, and, therefore, derived from plants which must have existed during the period when the rocks in which it is contained were laid down, so that the mere absence of plants in these beds affords no absolute proof that they did not exist in those far-away periods of the world's history. Indeed, if this view regarding the origin of the Laurentian graphite is accepted—which it has not been unanimously—there is as much carbon in the Archæan rocks as in equivalent areas of the Carboniferous system, so markedly characterised by its great deposits of coal.

Another indication of life in the so-called Azoic period is afforded by the beds of limestone which form so important members of the series. Limestone may, no doubt, under

* From Lake Huron, or from the Huron Indians.

† Silver, copper, zinc, manganese, and other ores, are obtained from the Erzgebirge region, while some of the principal deposits of petroleum are found in the Azoic rocks. Diamonds, rubies, sapphires, hyacinths, &c., are also common in the Archæan system.

‡ In one band of limestone in the Ottawa district there are from 20 to 30 feet.

certain circumstances be a chemical rock—that is, it may have been deposited from solution in water. More frequently, however, it is formed through the agency of living beings (Vol. I., p. 54), which have abstracted the lime from the sea, and in the end, either by the agglomeration of their shells, or by the decomposition of their calcareous coverings, heaped up the rocks under discussion. It is, therefore, more than likely that the Laurentian limestones have been formed in a similar manner.

Fig. 42.—PIECE OF LAURENTIAN ROCK WITH EOZOÖN CANADENSE.

The shaded parts are serpentine, the lighter limestone (Ophicalcite).

If so, the seas of the period must have swarmed with shellfish and other animals covered with limy mail, though owing to the intense metamorphism which the now crystalline limestones have undergone, all trace of the animals forming them has disappeared. In the Middle Laurentian, in addition to the thick veins and beds of iron ore already noticed, apatite or calcium phosphate (bone earth) is found. The iron may, according to Dawson, have been dissolved out and re-deposited by acids produced in the decay of vegetable matter,* as we see in the clay ironstones of the Coal formation and in bog-iron ores, while the calcium phosphate (phosphate of lime) is taken up by many animals, and forms their shells or skeletons, and is deposited when they die in beds on the sea bottom. If, therefore, we admit these data—and it is difficult to escape that logical inference—it is clear that so far from the Archæan period having been lifeless, it must have equalled, if not surpassed, some of the epochs succeeding it. This is quite possible, indeed, is highly probable, if we accept Dr. Sterry Hunt's estimate of the materials on which organisms could have fed and constructed their skeletons in those early times. He has calculated that the amount of carbon now sealed up as coal would, if diffused in the atmosphere as carbonic acid gas (carbon dioxide), "afford 600 times the quantity of that gas at present floating in the air," while the amount of lime held in solution in the ocean during the Laurentian age must have been much greater than nowadays. Hence, carbon and life being abundant, lowly beings such as those which originated the limestone beds and the graphite veins, could not only have freely existed in such an atmosphere, but have profited by a surplusage of the kind indicated.

It is, therefore, all the more tantalising to know that of this probable exuberance next to nothing has reached us. That little is the *Eozoön*, or Dawn animal,† which from the only species which has been at all well determined, having been found by Sir William Logan in Canada, has been called *canadense* (Fig. 42). Sir William Dawson, to whom is due the first intimation of its having been an animal, considers that it was a gigantic foraminifer, a lowly creature of the same order as Globigerina, and the other species already noticed (Vol. I., p. 352). Some observers—King, Rowney, Römer, Zirkel, Möbius, and others—doubt the animality of this *Eozoön*, contending that it is a mere crystallisation, or aggregation of mineral matter; and of late, lithologists seem to be rather tending in that direction, though, we believe, without facts potent enough to justify such a conclusion.

Sir William Dawson tells us that the best specimens of *Eozoön* occur as flattened or more or less irregular lumps or masses in certain layers of the Laurentian limestone. When these lumps are weathered, or slightly etched with acid, they show on the surface a regular concentric lamination, caused by thin fibres of limestone alternating with other mineral substances (such as serpentine, loganite, pyroxene, or dolomite), which, being more resisting than the limestone, project so as to show the lamination very distinctly

* Sterry Hunt: "Geology of Canada," p. 573, &c.

† Greek, *Eos*, dawn; and *Zoe*, life. Hence the Archæan rocks have sometimes been termed *Eozoic*, or *hypozoic* (*hypo*, under; and *zoe*), though, as that word expresses a positive opinion regarding the character of the *Eozoön*, it is not generally employed.

(Fig. 43). When these slices are examined under the microscope, it is seen that the *Eozoön* consisted of a chambered calcareous skeleton, into the spaces of which—formerly occupied by the delicate slimy sarcode, or

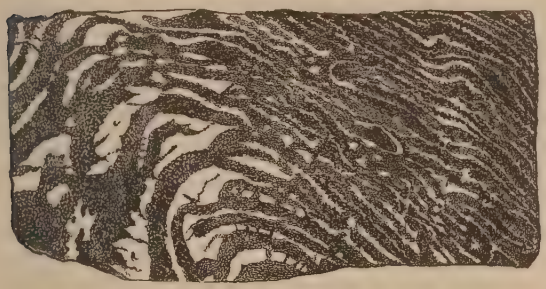


Fig. 43.—FRAGMENTS OF EOZOÖN CANADENSE, SHOWING THE LAMINATION.

(*Natural size. After Dawson.*)

substitute for flesh of the foraminifer—the mineral substances mentioned have infiltrated. If, therefore, the calcareous matter is dissolved out by acid, only the cast of the chamber in this insoluble serpentine, &c., remains, together with the passages by which these chambers were connected (Figs. 44, 45). This replacement of animal matter by a silicated mineral is not unknown in other rocks beside the Laurentian, so that the peculiarity described is by no means improbable. Accordingly, it would appear that the *Eozoön* was a gigantic foraminifer, which spread over the bottom of the Laurentian sea, tier above tier, each tier marked off from that above and below it by septa, perforated for the passage of bands of sarcode by which the chambers were brought into organic connection. Each band of sarcode was bounded by a thin "proper wall" (Fig. 44), perforated, to use the words of Alleyne Nicholson, by numerous minute tubes, by which the pseudopodia or prolongations externally of the sarcode reached the exterior. The various tiers of chambers were connected with one another by a canal system, and even separated from one another by the development of supplementary layers of calcareous matter, constituting what is called the "intermediate skeleton," though it is obvious that only the chambers of the uppermost tiers could have the power of giving out pseudopodia.*

Eozoön appears to have grown in reef-like masses, often of very great extent, and in its structure to have been most nearly allied to the living *Polytrema* and *Carpenteria*, though with points of resemblance to the *Nummulites* of the Tertiary period and the living *Calcarina*. It is, indeed, probable that the old *Eozoön* did in the Laurentian seas much the same work that was done by *Fusulina* in the Carboniferous, by *Nummulina* in the Eocene, and by *Globigerina* from the middle of the Cretaceous period until the present period. Thus it produced great beds of limestone such as the species named and the *Orbitolina texana* (Fig. 46) of the Cretaceous has done. The growth of *Eozoön* was, however—unlike that of its modern kindred, which are restricted in size by the budding of chamber to chamber in their shells being of a limited character—indefinite, and continuous like that of a vast

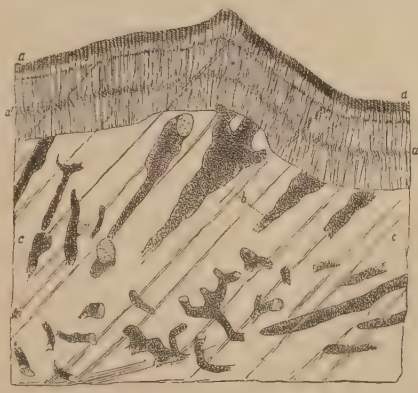


Fig. 44.—PORTION OF ONE OF THE CALCAREOUS LAYERS OF EOZOÖN, MAGNIFIED 100 TIMES.

(*After Carpenter.*)

a a, The proper wall of one of the chambers, showing the fine vertical tubes by which the pseudopodia reached the exterior, and which are slightly bent along the line of *a' a'*; *b*, *c c*, The intermediate skeleton, with canals.

tree. But each bud, though capable of living independently, remained in connection with

* Nicholson.: "Palæontology" (1862), p. 64.

the organism that developed it.* If, therefore, *Eozoön* is an animal—as there is good reason for believing that it is—it is by far the oldest being known, and its simplicity of structure

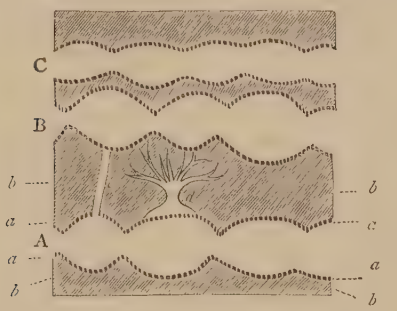


Fig. 45.—DIAGRAM OF A PORTION OF EOZOÖN.
(After Carpenter.)

A, B, C, Three tiers of chambers communicating with one another by constricted apertures; *a a*, The true shell-wall, perforated by numerous pseudopodial openings; *b b*, Intermediate skeleton; *c*, Passage of communication from tier to tier; *d*, Ramifying tubes in the intermediate skeleton. A, B, C, originally filled with the jelly-like *Eozoön*, are now occupied by serpentine, and the intermediate skeleton, originally limestone, is now crystalline marble.

is in keeping with the early period of the earth's history in which it appeared.

Its range was also wide. It is extremely abundant in Canada, and it is thought to have been detected in rocks of the same or of later age in Europe. But the so-called *Eozoön bavaricum* found by Gümbel in marbles associated with the grey or Hercynian Gneiss, so plentifully developed, along with the red or Bojan Gneiss, between the valley of the Danube and the headwaters of the Elbe, and the *Eozoön bohemicum*, which Fritsch described, from rocks of similar age in Bohemia (Vol. I., p. 189), are now generally admitted not to be of organic origin. As for the supposed traces of it in the Lower Silurian marbles of Connemara, in Ireland, they may be dismissed without much compunction; while the Eozoic representatives in Liassic times are, without any doubt, entirely unworthy of that name. They are nothing more than mineral infiltrations. The gigantic foraminifera—*Stromatopora*, *Archæocyathus*, and *Receptaculites*—which we meet with in the Cambrian and Silurian beds are, in some respects, allied to Eozoön, so far as their structure is concerned; and the mode of growth of *Stromatopora* must have closely resembled that of its more ancient predecessor, like it forming the substance of important limestones, and, in single masses, often attaining as much as three feet in diameter.†

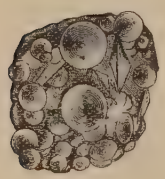


Fig. 46.—ORBITOLINA TEXANA, WHICH IN TEXAS FORMS, WITH ECHINODERMS AND CORALS, LIMESTONES 800 FEET THICK.

But if *Eozoön* is not an animal—and after examining many specimens, and hearing many arguments, and reading many papers, the present writer is still open to the reception of additional proofs for or against this assertion—no other portion of the Archæan rocks has revealed anything which can with the faintest right be so termed. This, indeed, is a staggering fact for those who hold to the organic character of *Eozoön*, since it seems difficult to understand why life was abundant in the earlier stages of the Archæan beds—which the Laurentian are—and absent from the younger or Huronian. Still, the whole question of the sequence, character, and origin of these pre-Cambrian rocks is so doubtful that for the present we must rest content with accepting facts as they are, in the hope that in time fresh light may dawn on what is at present so obscure.

* Philip Carpenter, in *Science for All*, Vol. V., p. 227.

† On the vexed question of *Eozoön* the reader may, among other works, profitably consult:—Dawson: "Acadian Geology" (1883), "The Chain of Life in Geological Times" (1878), and "Dawn of Life" (1875); Carpenter: *Proceedings of the Royal Society*, 1864, p. 545; *Quarterly Journal of the Geological Society*, XXI., p. 59; and XXII., p. 219; *American Journal of Science*, XVII. (Third Series), p. 196; and *Ibid.*, XVIII., p. 177. On the other side—that is, in advocacy of its non-organic character—the following writers have ranged themselves:—King and Rowney: "An Old Chapter in the Geological Record, &c." (1881); Möbius: *Palæontographica*, Vol. XXV., p. 175; Whitney and Wadsworth: "The Azoic System" (*Bull. Mus. Comparative Zoology, of Harvard*, 1884); &c., &c.

CHAPTER V.

The Palæozoic Rocks: The Cambrian, Silurian, and Devonian Systems.

The Range and Thickness of the Cambrian Beds—Provisional Classification and Correlation of the Formations entering into it—The Fossils which they contain—The Conditions under which they were Deposited—The Economic Products of the System, and Physical Features of the Regions in which it Predominates—The Silurian System—Its Range over the World—Classification and Correlation of its Formations—The Life of the Period—The Conditions under which it was Deposited—Its Economic Products and Scenery—Devonian and Old Red Sandstone System—Its Classification in Great Britain—Its Range in Foreign Countries—The Fossils Characterising It—Plants—Animals—Remarkable Armoured Fishes, and other Extinct Species—Probable Condition of the World at this Period—The Economic Products of the System—Its Scenic Characteristics, etc.

Scattered over several parts of Great Britain, but more particularly in North Wales and its borders, are a thick series of beds which on that account have been termed the *Cambrian*, Cambria being the ancient name of the Principality. In every case they lie unconformably to the Archæan system on which they rest, so that between the close of the latter period and the beginning of the one now under consideration, a long though indefinite lapse of time must have intervened. In the Longmynd Hills in Shropshire they are remarkably well developed, their thickness consisting at that particular spot of fully 25,000 feet, of sandstones, shales, and grits, exhibiting numerous ripple marks and rain-drops. Above these Longmynd, Harlech, and Menevian * groups (which are generally known as the *Lower Cambrian*), we come to a series of beds known as the *Upper Cambrian*, which consists of the Lingula † flags and the Tremadoc slates, strata 7,000 feet in thickness. In the north-western Highlands of Scotland they are represented by some 7,000 or 8,000 feet of conglomerates and sandstones, a few patches also occurring in the Outer Hebrides. In the south-east of Ireland the Cambrian beds attain a thickness of 14,000 feet, and it is probable that, when the entire series is examined, the extent of these rocks will be found even greater.

* Menevia, the Roman name of St. Davids.

† So called from the presence of *Lingula* (Lingulella) *Davisii*. (Fig. 49.)

On the Continent of Europe the Upper Cambrian underlies the Lower Silurian of Bohemia, the Thuringian Forest, France, Belgium, and Spain; and in Scandinavia both the Lower and Upper series are represented. In North America the Potsdam Sandstone of New York State is Lower Silurian, though in the Mississippi Basin and along the Appalachian Mountains, limestones and slates also appear, a fact which is also true of the system as represented on Nevada and other localities on the western slopes of the Rocky Mountains.

The following table presents at a glance the views most generally entertained regarding the classification of the Cambrian system, and its principal equivalents in different parts of the world:—

(1) **Lower Cambrian:**

(*a*) *Harlech and Longmynd beds*, including the *Oldhamia* Slates and Grits of Wicklow and Wexford in Ireland; the Fucoid and Eophyton Sandstones of Scandinavia; the Devillien of Belgium and the north of France (the Ardennes), greenish Quartzites and pale Slates containing *Oldhamia*; Stage B, Conglomerates and Grits of Bohemia (Fig. 47); the Arenicolite Slates of New Brunswick and Newfoundland, and the Eophyton Sandstone of the same regions, which were partly included in the so-called Taconic system of Emmons.

(*b*) *Menevian Group.*

Paradoxides Schists of Scandinavia; Stage

c. Grey and black Shales of Bohemia, the "Primordial Zone" of Barrande (Fig. 47); the Acadian Group of Eastern Canada, with *Paradoxides* (a trilobite, Fig. 49), and the Potsdam Sandstone of New York, which contains *Kutorgina cingulata*, and may be regarded as homotaxial with the English Hollybush Sandstone. To this group may, perhaps, belong the Calciferous Sandstones of the Mississippi Basin and the extreme West.

(2) **Upper Cambrian**:

(*c*) *The Lingula Flags* (in three stages); The *Olenus* Schists of Scandinavia; the Salmien (with *Lingula* and *Paradoxides*) and the Revinnien (with *Dictyonema sociale*) of the Ardennes; Stage D. (1*a*), Conglomerates and Grits of Bohemia (Fig. 47); slates with *Olenellus* at the Straits of Belle Isle in America.

(*d*) *Tremadoc Slates.*

Ceratopyge Limestone, and *Dictyonema* Schists of Scandinavia; Stage D. (1 B), Pisolitic Ironstones of Bohemia (Fig. 47); the Levi Limestone of Canada, containing *Dikelocephalus*, and other trilobites, and the Calciferous Sandstones of Western Canada and New York.

Life of the Cambrian Age.—Life during the Cambrian age seems to have been richer in species than in individuals, for, though the fossils found are indicative of seas meagrely inhabited, they show, notwithstanding the metamorphism of many of the strata, a remarkable variety of species for a period so early. In the lower beds there is considerable scarcity of forms, though, of late, an important addition has been made to the list by Dr. Hicks's discovery of thirty-two distinct species—sponges, crustacea, brachiopoda, and pteropods—in a single locality at St. Davids in the Harlech group of Pembrokeshire. Before that date the burrows and tracks of worms and a trilobite (*Palæopyge*), were the

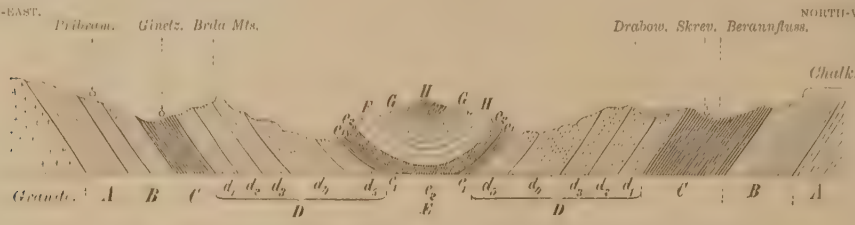


Fig. 47.—SECTION OF THE CAMBRO-SILURIAN BASIN OF BOHEMIA. (*After Barrande.*)

A, B, C, D, E, F, G, H, Barrande's different "Étages" or Stages from the Crystalline Schists through the Cambrian up to the close of the Silurian (each "Stage" marking a milestone in the progress of life from a lower to a higher condition), and the transition bed (H) which lead to the Devonian; d_1, d_2, d_3, d_4, d_5, Different divisions of the Stage D; e_1, e_2, Different divisions of the Stage E.

principal species known, in addition to the *Oldhamias*, one of which *O. antiqua* (Fig. 48), has been described from the Cambrian beds of the south-east of Ireland. For many years it was regarded as a zoophyte, allied to the sertularias and plumularias or sea-pens of our seas. It is now more generally regarded as akin to the corallines, those species of seaweed which are covered with an incrustation of lime, though it is still an open question as to whether it belongs to the animal or vegetable kingdom. The *Eophyton*, which Torrell has described from the "Fucoidal Sandstone" of Sweden, may also be a seaweed, though several of the markings described under the same name from the Potsdam Sandstone of New York are more justly regarded as only worm tracks, or even inorganic markings in the rocks. In any case, no one has as yet ventured to ascribe any supposed plant of the Cambrian period to a terrestrial origin. However, there was now no longer any doubt regarding the abundance of life in the seas of the globe, though we have still to learn whether the land was capable of supporting

Fig. 48. — OLDHAMIA ANTIQUA (FORBES), A SUPPOSED SEAWEED OF THE LOWER CAMBRIAN ROCKS OF IRELAND.

FOREST VEGETATION IN SENNAAR

AFTER AN ORIGINAL DRAWING BY R. HARTMANN

vegetation or air-breathing animals. Indeed, the wonder is that after the lowly and even problematical *Eozoön*, forms so highly developed should appear. It is thus extremely doubtful whether, between them and the poor fauna of the Archæan rocks, a vast series of fossiliferous beds has not disappeared, or is still to be discovered containing the missing forms (p. 62). The species are by no means low in the scale. Some of them, indeed, are highly organised, and not a few of the genera combine in themselves characters

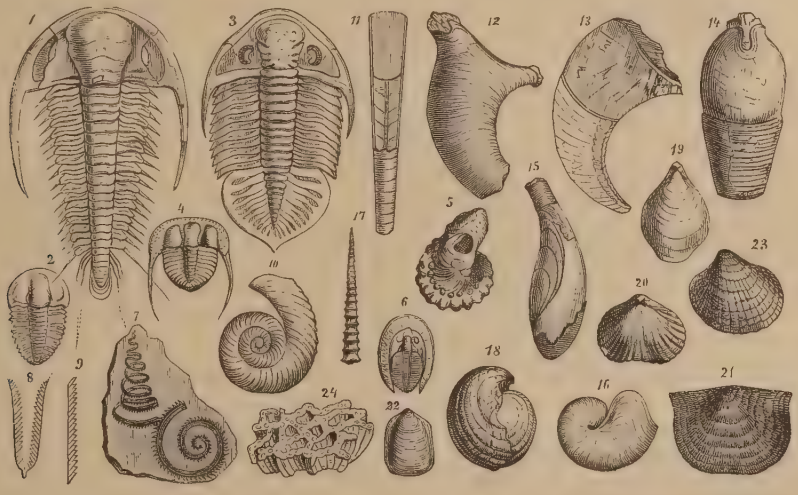


Fig. 49.—CHARACTERISTIC FOSSILS OF THE SILURIAN SYSTEM, AND PART OF THE CAMBRIAN.

1, Paradoxides bohemicus; 2, Ellipsocephalus hoffi; 3, Dalmanites hausmanni; 4, Trinucleus ornatus; 5, Phacops cephalotes; 6, Harpes venulosus; 7, Graptolithus turriculatus and G. convolutus; 8, Didymograptus (Graptolithus) bifidus; 9, Monograptus (Graptolithus) römeri; 10, Lituites; 11, Orthoceras; 12, Phragmoceras; 13, Cyrtoceras; 14, Gomphoceras; 15, Ascoceras; 16, Bellerophon bilobatus; 17, Tentaculites ornatus; 18, Pentamerus knightii; 19, Terebratula melonica; 20, Rhynchonella wilsoni; 21, Leptæna depressa; 22, Lingulella (Lingula) davisii; 23, Cardiola interrupta; 24, Halisites (Catenepora) catenularia.

not now found in any one order or genus, while others, like *Lingula* and *Discina*, survive as genera to the present day, though the particular species entombed in the Cambrian rocks have long ago disappeared. Among these are the singular *Trilobites*, animals so extraordinary, that they may be regarded as the type of not one, but a variety of later forms of the order Crustacea—the crab and lobster order—to which they belong (Fig. 50). They now appear for the first time, though they persist through several of the subsequent formations. They derive their name (*Trilobites*), from the fact of their bodies being usually more or less distinctly three-lobed. The body was protected by a well-developed shield or crust, which covered the whole of the back of the animal, and was entirely without any appendages, except the eyes. The trilobites were, however, flexible, for, as the state in which many of them are found proves, they could roll themselves up in the ball-like form so familiar in the common wood-louse. The eyes (Figs. 49, 50, 51) were compound, and consisted of "an aggregation of facets, covered by a thin cornea," though invariably sessile, that is, not stalked like those of the crab and lobster, and generally crescentic or kidney-shaped. They varied in size, from some not much larger than a bean to others two or three feet long; and, though they are almost *per se* in form, they may have been distantly allied to the living king crabs and horse-shoe crabs of the warmer seas. They seem to have been capable of swimming and crawling, and, using their snout as a shovel, could burrow like the modern king crab; some of the species, as we have seen, being

able to roll themselves up, and thus present an armoured front to their enemies. The group persists into the Carboniferous period;

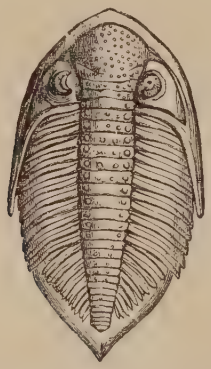


Fig. 50.—BACK OF ASAPHUS CAUDATUS, WITH THE EYES WELL PRESERVED. (*After Buckland.*)

but the age of Trilobites was in the period we are now sketching. The Brachiopods—lamp- or carriage-spring shells (represented by *Lingula, Orthis*, and *Discina*)—now made their appearance, while ordinary shell fish are represented by pteropods, heteropods, and even by bivalves. Sponges, sea-lilies or stalked feather star-fishes, star-fishes, and

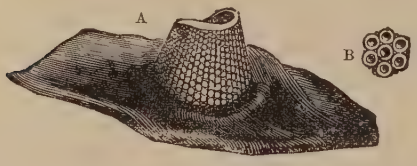


Fig. 51.—A, SIDE VIEW OF THE EYE OF ASAPHUS CAUDATUS, MAGNIFIED (*After Buckland*). B, MAGNIFIED VIEW OF PORTION OF EYE OF CALYMENE MACROPHTHALMUS (*Hoeninghaus*).

sea urchins appear, and, in addition to the Trilobites and other species, the fossil markings named *Protichnites* and *Climactichnites*, are believed to be the footprints of some huge crabs or other crustaceans walking over a muddy shore. Finally, not to enumerate the many forms of life in the Cambrian rocks, the Cephalopoda or Cuttlefish order, one of the most complex of its class, suddenly appear in the Tremadoc beds in the form of the *Orthoceras*, a species living in a chambered shell, though, as the name signifies, of a straight rather than a curved shape (Fig. 49,11). Its presence has been accounted for on the theory of migration. In America and Great Britain the Cambrian contains many species either identical or closely resembling each other. Hence Dr. Hicks suggests that the home of the earliest forms of life seems to have been somewhere towards the south-west, and possibly not far from the Equator, a suggestion which he considers is borne out by the fact of the higher invertebrates (such as bivalves, univalves, and cuttlefish in shells), appearing in Spain and Wales at an earlier period than they do in north-western Russia.* This theory is only acceptable on the supposition that the Atlantic was in existence during the Cambrian epoch, and that during that period the European continent lay, as now, to the eastward of Great Britain, an assumption to which exception might be taken.

Physical Conditions of the Period.—That a large portion of the Cambrian beds is formed of the worn-down materials of the Archæan rocks admits of no doubt. Many of them—the Longmynd Rocks, for example—contain fragments derived from those which immediately preceded them,† though it is equally open to assertion that a large portion of them may have been formed by the erosion of the vast series of strata which, there can be little doubt, intervened between the Archæan and Cambrian periods, but of which as yet no trace has been obtained. The grey and reddish grits (what the old writers used to term "greywacke"‡), conglomerates, shales, schists, slates, etc., may be regarded as of a purely clastic origin. But the diabase-tuffs and other imbedded sheets which occur towards their base in Wales point to a period of volcanic action, during which not only were

* Hicks, *Quarterly Journal of the Geological Society*, Vol. XXXI., p. 555.

† Callaway, *Quarterly Journal of the Geological Society*, 1886, p. 481, and *Ibid.* 1879, p. 661.

‡ German, *Grauwacke*, a name at one time used for the entire series of "Transition rocks," or what are now known as the Archæan, Cambrian, and Silurian. It is at present, when employed at all, found convenient to describe the grits, breccias, or conglomerate beds in these systems.

plutonic rocks erupted, but beds of their ashes and other *débris* were formed in the sea.

To admit of this extensive erosion there must have been great elevation of the Archæan country before the first of the Cambrian beds were deposited. Now, as we have seen that many of the strata comprised in this formation are of vast thickness, the amount of erosion must have been enormous; and, as the Archæan rocks of Scandinavia still appear on the surface, the chances are that the country in which they are found was again and again upheaved, otherwise, considering the masses of Cambrian strata which lie at its base, it would have disappeared in the process of forming the latter. The ripple-markings, sun-cracks, and false bedding of many of the Cambrian beds would seem to indicate that they were laid down in shallow water, and were now and again uncovered; while the casts of jelly-fish which Nathorst believes that he has detected in the Cambrian beds of Sweden indicate tranquil seas. Sir Andrew Ramsay, on considering the different appearances presented by the Scottish, Irish, and Anglo-Welsh strata of this age, has suggested that the first-named were deposited in an inland basin, or basins, at a period when continental land occupied what is now the area of the North Atlantic, with an open and shallow sea to the east and south-east of that continent. This land, Dr. Hull ventures to think, was probably disposed in ridges and hollows, "trending in directions parallel to that of the Outer Hebrides and of the Archæan ridge traversing the British Islands," between which ridges, lakes, or arms of the sea may have been interspersed.* The English and Irish beds indicate an alternation of marine and fresh-water beds, the latter being unfossiliferous, though the series became latterly entirely marine, owing to the continued subsidence of the land. It is, however, certain that since their deposition the Cambrian beds have been much disturbed, signs of severe metamorphism being everywhere apparent, the rocks in some parts of the continent being mere crystalline schists, while plications, dislocations, and disturbance of all kinds are everywhere visible in these members of what used to be described as part of the Metamorphic system.†

Science and Industrial Aspects.—So far as scenery and economic value are concerned, there is not a great deal of difference between the Cambrian and the Archæan rocks which precede them, or, indeed, between them and the Silurian, which follow. Rugged elevated ridges and bold mountain ranges—such as nearly every person is more or less familiar with in the Welsh and Scottish Highlands, or in the tracts which we have already described as composed of these rocks—form the chief features of these metamorphic regions. Any one who has noticed the narrow gorges, splintering peaks, and irregular picturesqueness which are so characteristic of Norway, Cumberland, the Northern Hebrides, and those parts of Canada and the United States where the formations in question prevail, will have observed that these peculiarities are due to the manner in which the schists and slates of which they are so largely made up weather under the action of rain and the atmosphere generally.

Slates are the principal economic products yielded by the Cambrian beds, though, in common with the Laurentian and the Silurian rocks, they are penetrated by metalliferous veins of great richness, especially those of tin, copper, silver, iron, and gold-bearing quartz. The best-filled mineral veins are, indeed, found in these ancient strata. Hence, though the Metamorphic rocks form a poor soil and, owing to their hardness, disintegrate slowly,

* Ramsay, *Proceedings of the Royal Society*, 1874, p. 334; Hull: "Contributions to the Physical History of the British Isles," p. 61.

† Marr: "Classification of the Cambrian and Silurian Rocks" (1883); Hull: "Physical Geography and Geology of Ireland" (1878); Lapworth, *Geological Magazine*, 1881, p. 260, and *Proceedings of the Birmingham Philosophical Society*, Vol. III., p. 237; Hague: *Report of the U.S. Geological Survey* for 1881–1882; Callaway, *Quarterly Journal of the Geological Society*, Vol. XL., p. 582, Vol. XXXIII., p. 652, and Vol. XXXVI., p. 237; Hughes, *Ibid.*, Vol. XXXIV., p. 137, and Vol. XXXV., p. 682; etc., etc.

they are nearly everywhere the centres of great mining industries, and of a population more thriving than refined, and more independent (as is the wont of mountaineers living retired and little accessible to law) than ready to benefit by the advances of civilisation, and to obey those restrictions on individual liberty which are essential to a well-ordered society.

Silurian System.*

Lying conformably over the Cambrian rocks, we find in many parts of Westmoreland and Cumberland, the hilly country of Southern Scotland—in the vicinity of Moffat, for example, and most likely in the area to the south-east of the Caledonian Canal also — a thick series of slates, shales, flagstones, sandstones, grits, conglomerates, and occasional calcareous layers and irregular (or "lenticular") beds of limestone. They also appear in Norway and Southern Sweden, in the islands of Dagoe and Oesel in the Baltic, and eastward through wide tracts of Livonia and Esthonia to the south of Lake Ladoga in almost horizontal beds, appearing again in a tilted-up condition on the sides of the Oural Mountains. In Bohemia there are patches of them, and in the Thuringian Forest, the Harz, the Fichtelgebirge, the Frankenwald, in the Eastern Alps (Fig. 47), in the province of Brabant in Belgium, in Brittany and Normandy, and in Spain and Portugal, rocks of the same age are more or less developed.† Crossing the Atlantic, they range from near the mouth of the St. Lawrence River, along the shores of the great lakes, far into the regions lying north and west of Wisconsin and Minnesota, and along the western flanks of the Alleghanies into Alabama, with patches here and there between the Alleghanies and the Mississippi, so that these rocks, concealed under younger formations, probably extend "throughout the interior Continental Basin. They appear in the Rocky Mountains, and occur, with their typical fossils, in the islands of the Arctic Archipelago. They have been recognised in the Cordilleras of South America, in the Himalayas, and in Australia." In Russia, most likely, they stretch under the drift-covered plains of the North, and in the British Islands there can be but little doubt that they extend through the greater part of their area buried under younger formations.‡

But it is in South Wales that this system of beds is most typically developed, and from the fact of part of the region having been the home of the ancient British tribe of the Silures, Sir Roderick Murchison § applied to it the name it has ever since borne. In this part of England the Silurian system attains a thickness of between nineteen and twenty thousand feet, and is divided by the fossils which it contains into a *Lower* and an *Upper Silurian.* These two divisions are again made up of a series of groups, each characterised by the presence of one or more typical fossils, the names of the groups being derived from the localities where they were first studied, though they are for the most part, represented by homotaxial beds in the other parts of the world already mentioned as containing Silurian strata.

The following table may be regarded as expressing, in an approximate manner, the views most generally entertained on this subject:—

(1) **Lower Silurian.**

(*a*) *Arenig*‖ *or Stiper Stone Group.*

Skiddaw slates of Westmoreland and Cumberland, the Ballantrae shales of south

* Between the Cambrian and the Silurian proper Professor Lapworth, whose researches among rocks of this age give him every right to speak as one having authority, proposes to intercalate an "Ordovician" system (from the tribe of the Ordovices, who inhabited North Wales), which is practically the Lower Silurian of Murchison or the Upper Cambrian of Sedgwick. This view has been adopted by Mr. Jukes-Browne in his recent excellent digest of our knowledge of stratigraphical geology. However, without doubting the wisdom of my learned friend's views, it is perhaps better, in a general sketch so elementary as that on which we are engaged, to abide by the classification almost universally adopted. There is, indeed, some ground for believing that in time the Cambrian and Silurian will be regarded as merely divisions of one great system.

† See the geological maps of the British Islands (Vol. I.) and of Central Europe in this volume.

‡ James Geikie: "Outlines of Geology," pp. 267, 268.

§ "Siluria: A History of the Oldest Rocks in the British Isles and other Countries," fourth edition (1867).

‖ From the Arenig Mountain in Merionethshire.

Scotland, and possibly some of the Durness and Eriboll beds of Sutherlandshire; the "stiper stones" form a celebrated ridge in Shropshire; Lower Graptolite shales of Scandinavia, limestone beds with *Orthoceras*, and the blue clay with sandstone bands which, at Revel in Russia, have been bored to a depth of 800 feet without bottom being reached, the Ungulite sandstone with shells of *Obolus apollinis*, or "Ungulites," the Alum slate, and the Glauconite sand of north-west Russia; the Quartzite Stage D of Barrande, comprising various divisions, of which d_1 contains the Krušnahora, Komorauer, and Rokycaner schists of Lipold and Krejči; d_2, the Brda schists of the same geologists; d_3, their Vinicer; and d_4, their Zahořaner schists; while d_5 of Barrande is equivalent to the Königshofer and Kossower schists of these investigators* (Fig. 47). In North America the Arenig group does not seem to be developed.

(*b*) *The Llandeilo Group.*

The volcanic tuffs and lavas, with sedimentary strata of the ordinary character at their base, of Westmoreland and Cumberland; the Ardwell, Moffat black shale, Queensberry, Dalveen, Lowther, Upper black shale, and Carsphairn groups of the south of Scotland; the grey, greenish, and purple grits of the south-east of Ireland, particularly the "Dark Shale series" of the Ballymoney cliffs near Courtown, and of Wexford and Waterford; the Lower Orthoceratite limestone, and the Upper Graptolite schists of Scandinavia; the Limestone with Glauconite grains, and many fossils, particularly *Orthis calligramma*, and *O. extensa*, Orthoceratite limestone and Marl beds, and Bituminous limestones of Russia.

(*c*) *The Bala and Caradoc Group.*

Part of the volcanic tuffs and lavas of the Borrowdale beds, and all of the Coniston limestone and shale of Westmoreland and Cumberland; the conglomerates, grits, shales, and bands of limestone developed in Dumfries-shire, Peebles-shire, and the south-west of Ayrshire; the Ballymoney series, *e.g.*, at Portraine on the Dublin coast; the Orthocerite limestone and lower Encrinital schists, the calcareous and argillaceous Flagstones, and the calcareous Sandstones of Scandinavia; the Wesenberg limestone and marl, the Lyckholm yellow or

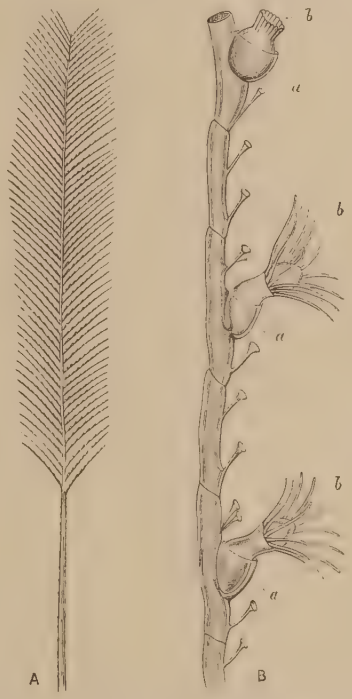


Fig. 52.—PLUMULARIA, MODERN SEA-PEN OR SEA-PLUME. (*After Allman.*)

A, Stem and branches of Plumularia, natural size; B, Branch of Plumularia, magnified; *a a*, Calycles or hydrothecæ (polyp-cups); *b b*, The Hydranth or Polypites (individual polyp).

grey compact limestone, and the Borkholm limestones and marls of Russia. In America the Trenton period† comprises the Llandeilo and Bala groups, in addition to much of the Lower Llandovery, which, in England, is the next highest one of the series; to this stage also most likely belongs the Quebec group of

* The exact Welsh equivalents of these beds cannot well be given. Some of them, which for convenience' sake we have lumped under the Arenig group, are unquestionably of later date; though, as this cannot at present be ascertained, it is better not to attempt the homotaxis. They are, in any case, all Lower Silurian.

† In the Stinchar limestone of south-west Ayrshire there are fossils of the Trenton limestone, not occurring in any other British rock, *e.g.*, *Maclurea logani*, *M. magna*, *Murchisonia angustata*, etc.

Canada, though it includes several formations of different stratigraphical position.

(*d*) *The Lower Llandovery Group.*

In the north of England the Lower Llandovery group is not represented; but in the south of Scotland it appears in the sandstones and conglomerates of Quarrel and Mulloch Hills in the Girvan Valley; in Russia, in the Middle Silurian of Schmidt;* and in America, as we have seen, it is represented by some of the Trenton group, as well as by those known as the Cincinnati (Hudson River) and Utica groups.

(2) **Upper Silurian.**

(*e*) *Upper Llandovery Group.*

In Wales this consists of the Tarrannon shale and the May Hill sandstones. In Scotland they are represented by the grits and flags of Girvan and the Moffat shales, containing graptolites. In Ireland they are developed in Meath, County Clare, and along the shores of Belfast Lough. In Sweden the *Pentamerus* (Fig. 49, 18) limestone and the *Rastrites* (Fig. 54) schists are, by their graptolites, identified with the Birkhill shales of Scotland. In Russia some of the Middle Silurian comes under this group; and so also in Bohemia does Stage E of Barrande, which consists of shales with calcareous nodules—his "Untere Kalk"—and may be regarded as equivalent to Lipold and Krejči's Littener, and Kuchelbader, or Lochkower schists (Fig. 47). In America the Niagara period represents the Upper Llandovery, in the shape of the Clinton and Medina groups of which it is composed.

(*f*) *Wenlock or Salopian Group.*†

In the Lake District the Coniston flags and grits belong to the lower portion of the group, while the dark-blue flags and grits of the Bannisdale slates must, most probably, find a place in the upper division of the Wenlock. In the south of Scotland the Upper Silurian is not divisible in the groups so marked in other parts of the kingdom, its members being referable mainly to the lower portion of the newer division of the system; the Bargany group of the Girvan district is, however, referable to this division, and the Riccarton beds of the southern uplands, and of Mosspiel on the Borders, Dr. Lapworth considers Wenlock. In Scandinavia it is sufficiently marked by the coral limestone containing *Omphyma turbinatum*, etc., and the encrinital schists with orthoceratites, and *Gomphoceras pyriforme* (Fig. 49, 14); in Russia, the Lower Oesel group represents it; and in Bohemia, what Barrande calls the "third fauna," the Lower Silurian being the "second," and the Cambrian the "primordial." Stages F and G—the Koniepruser and Braniker schists of Lipold and Krejči—probably represent this, and in some respects the last group of the Upper Silurian also, Barrande's stage H—the Hlubočeper schists of Lipold and Krejči—being to some extent marked by fossils, which indicate the approach of the Devonian, though it also contains Ludlow species (Fig. 49). In America the Niagara shale and limestone are the trans-Atlantic representatives of the Wenlock.

(*g*) *The Ludlow or Clunian Group.*‡

This series appears in the north of England in the shape of some of the Bannisdale slates, and in the Hay Fell and Kirkby Moor flags. In Ireland the Croaghmarhin beds of the Dingle promontory and the Salrock beds of Galway are probably of this age; the brown shales of Lesmahago in Lanarkshire, and the sandstones, flags, and shales of the Pentland Hills, also belong to this group. In Scandinavia it is represented by the sandstones of Kaerrstorp and Æved of South Gothland, and it is possible by certain limestones and shales of Scania in Sweden, though Mr. Marr is inclined to class the latter with the Wenlock group; the Upper Oesel group of Russia are Ludlow, while the Tilestones, which showed a transition to the Devonian system, are also represented; in America the Salina formation, composed of the Guelph limestone and Onondago Salt beds, nearly barren of

* Schmidt: "Untersuchungen über die Silurische Formation von Estland, Nord-Livland und Oesel" (1858).

† So called by Mr. Jukes-Browne, from being well developed in Salop, or Shropshire. The Llandovery is also sometimes known as the Valentian (Lapworth), from the Roman name of the province in the south of Scotland where its beds are found.

‡ From Clun Forest, in Shropshire, where it is well developed.

fossils, is not represented in England, but both it and the Lower Heidelberg and Oriskany formations are Ludlow.

This classification, like those which preceded it, and like those which follow, is only presented as a provisional arrangement. It exhibits in a condensed form the result of long research by many geologists, though, as some of the beds noted are not yet fully examined, and discoveries are constantly in progress, it is quite possible that in time some

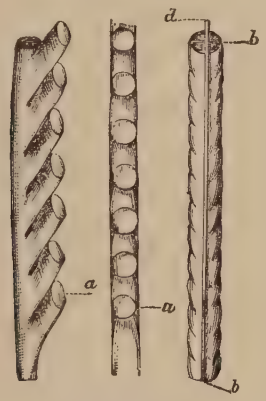


Fig. 53.—MONOGRAPTUS BOHEMICUS (BARR.) IN RELIEF.

a, Calycles; *b*, Common canal; *c*, Dorsal groove; *d*, Solid axis.

alterations may be demanded in this homotaxis. These, however, are not likely to be either extensive or important.*

Life of the Silurian Age.—In this period we find life not only frequent but varied. Species which were abundant in the Cambrian epoch have died out or begun to wane, while others for the first time make their appearance (Fig. 49). Still, however, the animals are mainly marine. Foraminifera and sponges are plentiful, the latter more especially being found in great numbers throughout the entire formation. Among other peculiar forms are *Receptaculites* and *Ischadites*, which may be regarded as genera intermediate between the two groups of animals just mentioned. But the species most characteristic of the Silurian are the graptolites, of which many species, genera, and even families, have been described. Some of them are portrayed in Figs. 24, 49, 53, and 54, and from the glistening line-like appearance which they present when seen on the dark shales, fully justify the name which they have obtained.† They were closely allied in structure to the sea firs and sea pens of our modern seas, such as the Plumularia (Fig. 52) and other plant-like zoophytes or Hydrozoa. The little notch-like markings on the edges of these graptolites indicate the little cups or cells which were inhabited by the individual polyps, which entered into the composition of these compound animals.

Like their modern relatives, most of the Graptolites must have been fixed on rocks or shells, or in some other way as stationary as the seaweeds, for which they are apt to be mistaken. But it is not unlikely that some of those which radiated, like *Loganograptus*

* In addition to the memoirs and works already cited, the following have been consulted :—For Wales, Ramsay : "Physical Geography and Geology of Great Britain" (1878) and "Geology of North Wales" (1872); Marr and Roberts, *Quarterly Journal of the Geological Society*, Vol. XLI., p. 476; Marr, *Ibid.*, Vol. XXXVI., p. 277; Hicks, *Ibid.*, Vol. XXXI., p. 167, and Hopkinson and Lapworth, *Ibid.*, p. 635; Lapworth, *Annals of Natural History*, Ser. V., Vol. III. (1880); Sollas, *Quarterly Journal of the Geological Society*, Vol. XXXV., p. 475.

For the Lake District: Marr, *Quarterly Journal of the Geological Society*, Vol. XXXIV., p. 871; and Aveline and Hughes: Geological Survey (Sheet 98, S.E. Explanation pp. 6-13), and Ward's "Geology of the North Part of the English Lake District."

For the Scottish groups: Lapworth, *Quarterly Journal of the Geological Society*, Vol. XXXIV., p. 240, and Vol. XXXVIII., p. 538; B. Peach and Horne, *Nature* (1884), p. 31; Callaway, *Quart. Journ. Geol. Soc.*, 1883, p. 355; Forsyth, *Trans. Geol. Soc. Glasgow*, Vol. VII., p. 358; etc.

For Ireland, Hull: "Physical Geology of Ireland," p. 22; Kinahan: "Geology of Ireland," Chap. III., "Geological Survey of Ireland," Sheets 76, 77, 83, and 84; and generally Hull's "Contributions to the Physical History of Great Britain." In Marr's "Classification of the Cambrian and Silurian Rocks" a good account of the foreign groups is given. It should be studied in connection with Barrande's "Système Silurien" and "Trilobites" (1871). In the Reports of the Geological Surveys of Canada and the United States, the American beds are discussed. See also Callaway, *Geological Mag.*, June, 1878.

For Scandinavia, Angelin's "Palæontologica Suecica," Kjerulf's "Norges Geologi," and Johnstrup, *Beret. om Mëdet. Skand. Naturforsk.*, 1873, p. 299, may be consulted.

† Greek, *Graptos*, written; and *lithos*, stone.

(Fig. 24 D), from a central film might, if this central portion was a hollow vesicle, have been able to float in the sea or live on the surface of the water. These forms (*Didymograptus, Dicranograptus, Diplograptus, Rastrites,* etc.) are especially characteristic of the

Fig. 54.—A A, RASTRITES; B, CYRTOGRAPTUS.

Upper Cambrian and Lower Silurian, while *Graptolites* and *Retiolites,* though found in the lower series, are more pre-eminently species of the Upper Silurian.* The entire group of the Monograptidæ (the species with cellules along one side of the stem) are exclusively confined to the Upper Silurian, which division is also distinguished by the great number of corals found in its beds, nearly eighty species being recorded from the Wenlock limestone alone. Unless we except the genus *Dictyonema* (though it is possibly a Polyzoön, and therefore akin to the Flustras and sea-mats of our seas, which came in early and lived to the Devonian), no graptolite seems to have survived the Silurian period. They appeared suddenly, and just as suddenly disappeared; though during the time when they flourished they were so widely spread that many of the species seem to have been common to Europe, North America, and Australia. Corals were also exceedingly abundant all through the Silurian, particularly in the Wenlock limestone of England and the Niagara limestone of America, which is so studded with them as to justify the belief that it was an ancient coral reef; though in the Cambrian these true stony corals, now so profuse in number and species, were entirely unknown. The species belonged almost entirely to the Tabulata or floored corals and the Rugosa or wrinkled ones. In the former—*Halisites* (Fig. 55), for example—the cells are often hexagonal and floored, or partitioned across at intervals with horizontal plates. In the Rugosa the cell has strongly marked radiating plates, the "floors" characteristic of the Tabulate group being absent or reduced to small dimensions. In modern times very few corals are formed on these plans, though the Rugose ones are more like the reef-building species than the Tabulate forms are. In these Palæozoic corals the radiating laminæ begin with four and increase by multiples of that number, while six and multiples of six is the rule which holds good in modern species.

The star-fish order (*Echinodermata*) are largely represented in the Silurian, especially in the shape of crinoids or stalked forms, and the Cystideans, which are more particularly

Fig. 55.—HALISITES CATENULARIA.

characteristic of the Bala and Caradoc period. True star-fishes, brittle stars, etc., are not

* Nicholson: "Monograph of the British Graptolidæ," Part I., General Introduction (1872); Herrmann: "Die Graptolithen-familie Dichograptidæ" (1885), etc., etc.

infrequent, but true sea urchins are found only in the Upper Silurian in the shape of the curious genus *Palæchinus*. The Crinoids or stalked feather star-fishes, now so extremely rare in modern oceans, seem at that time to have covered the bottom for miles at a stretch in thickets so dense that their remains make up considerable beds of limestone. Worm-tracks and tubular worm-cases attest the presence of other Orders, while Crustaceans now for the first time form a marked feature in the fauna of the ancient seas. Trilobites are still abundant. This extinct family lived on through the Devonian period, and died in the Carboniferous. But it was in the Silurian that it attained its zenith of prosperity. Less aberrant species, however, began to appear, and among these is *Pterygotus anglicus*, one of an extinct order of king crabs, which was fully six feet in length; while, not to enumerate a host of other species, Mollusca, in the shape of shelled cuttle-fishes like *Orthoceras* (Fig. 49, 11), and Brachiopoda like *Pentamerus* (Fig. 49, 18), became very numerous both in species and in individuals. So abundant were the Brachiopoda that the Silurian is sometimes termed the age of this Order of animals. One small species (*Orthis biloba*) is, indeed, so abundant in the Buildwas shale that a cart-load of it was found, by careful washing, to contain no fewer than 4,300 specimens, in addition to a much greater bulk of other brachiopods, amounting altogether to 10,000 specimens at least, while from several tons' weight of the shale some 25,000 specimens of the species of *Orthis* mentioned have been obtained.* The cuttle-fishes living in chambered shells are so plentiful, both in the coiled and straight forms, that from the Silurian Basin of Bohemia alone Barrande has described over 1,120 species. Of *Orthoceras* alone there are 554 species, while 350 different forms of *Cyrtoceras* are described. Some of these ancient cephalopods were six feet in length, and, what is most interesting, among the genera appears *Nautilus*, a genus of which one species—one of the two modern representatives (the pearly and paper nautili) of cuttle-fishes in shells—still exists.

However, what are still more important than these, are the scorpions and winged insects, which were discovered during 1884 in rocks of Silurian age. The scorpions (two species of *Palæophoneus*) were found, the one by Dr. Lindström in Wenlock rocks in the island of Gothland, the other by Dr. Hunter in the Ludlow beds of Lesmahago in Scotland. Both had a poison gland, so that they must have preyed on other land species. That these species existed is shown by the discovery made, almost at the same time, by M. Douville in the Caradoc beds of Juraques, Calvados (France), of a species of cockroach (*Palæoblattina*). This is, therefore, the oldest winged insect known. Hitherto, no vertebrata or back-boned animals have been seen. They are absent from the Lower Silurian, but by the time the Upper Silurian is reached, fishes appear, the remains found being the bony bucklers or head shields of species allied to the mail-covered garpike of the American rivers. These species have been described as *Pteraspis*, *Cephalaspis*, etc., while an *Onchus* is represented by its defensive spines. These forms of fish, the Cestracionts, though living to the beginning of the Tertiary period, are now represented by only one species, the Port Jackson shark (*Cestracion philippi*), the mouth of which is—as were those of its ancient allies—covered with large polygonal, obtuse enamelled teeth, like a tesselated pavement. We also find in the Upper Silurian the shagreen-like skin of other species, which, like the shark and dog-fish Order, were covered with prickly scales. The fishes (*Thelodus* and *Sphagodus*), as well as *Onchus*, have been found plentifully in the Upper Ludlow "bone bed," while from the Upper Silurian of Bohemia there come some five or six species of Ganoids (the garpike form), Cestracionts, or Selachians (the Cartilaginous-boned fishes), like sharks (Fig. 39).

But what gives the Silurian system its main palæontological interest, next to the presence of its scorpions, cockroaches, brachiopods, chambered cuttle-fishes, graptolites,

* Davidson and Maw, *Geological Magazine*, 1881, p. 101.

and fishes, is the fact that now, for the first time, we have indisputable plants. The land plants consist of the stems of *Sagenaria*, a Lepidodendron or gigantic club-moss allied to the "witches' tethers" of British moorlands, and the seed-like sporangia of other plants of the same Order. In the Lower Skiddaw slates of the Lake district plants have been found which Dr. Alleyne Nicholson has described as *Buthotrephis harknessii* and *radiata*, though, perhaps, the two species are fragments of the same plant. Sir William Dawson, however, is of opinion that they were not seaweeds as their discoverer believes, but distant relatives of the mares'-tails or equiseta of the swamps, and therefore allies of the Annulariæ and Calamites of the Devonian, and Carboniferous periods.

In the Cincinnati group of America a fern-ally (*Sphenophyllum*), and *Protostigma*, the stem of a relation of the club-mosses, have been discovered. From the same beds a *Psilophyton*—a relation of the pillworts—has been disinterred, though it is still a moot question whether this is not a zoophyte rather than a plant; while in the Silurian slates of Angers in the south of France is found a fern (*Eopteris*), or, if this is not its true character, a very fern-like plant. Again, if we allow that some of the "fucoid"-like forms, which have been described, are very dubious species—some of them having been imitated by setting crustaceans, annelids, and molluscs to crawl over wet mud*—the *Chrondites verisimilis* of the Ludlow Rocks of Midlothian, and other species from the Upper Silurian, are perfectly unmistakable seaweeds. In the Upper Silurian we also find land plants, such as the *Glyptodendron eatonense* of Claypole, a tree-like club-moss, which has been unearthed from the Clinton limestone of Ohio. In both Bohemia and Wales similar plants have been found, and Sir William Dawson considers—incorrectly most botanists believe—that a fragment of wood from the Ludlow Bone Bed is a prototype of the pine tribe (*Prototaxites*). These plants—and no doubt many more remain to be discovered—afford ample proof that during the Silurian age a considerable vegetation had made its appearance—a vegetation dense enough in places to form the seams of anthracite which are occasionally met with in Silurian beds. Altogether, there must be close upon 11,000 species of fossils recorded from the Silurian strata.

Physical History of the Silurian Age.—The circumstances under which the Silurian beds were formed admit of various opinions. However, it is certain that before they began to be laid down there must have been a sinking of the country, the outlines of which may be regarded as indicating the range of the Cambrian formations, for all of the Silurian beds are eminently marine. That the period was one of violent disturbance from volcanic outbursts is inferable from many of the groups composing the system being permeated by volcanic products, some of them, indeed, being made up of tufas, ashes, etc., arranged more or less under the influence of the water into which they were discharged. It may also be stated with something like confidence that during the Silurian period all, or at least the greater part, of the British Islands were under the sea. Sir Andrew Ramsay, indeed, does not hesitate to state his belief that what is now the United Kingdom was during that age of the Earth—at all events during the Lower Silurian epoch—a series of volcanic islands like some of those we have already described (Vol. I., pp. 163–67), with Archæan land to the northward. (Fig. 41).

Between the Upper and the Lower Silurian there is in Britain a decided unconformability, so that though, in the easy way geologists have of dealing with millions of years, this and the Upper Silurian are classed in one system, there cannot be any doubt that an immense period of time elapsed between the close of the one and the beginning of the other system. At the termination of the Lower Silurian there must have been an elevation of the country, which had been lowered during a stretch of time, the extent of which we have no means

* The conclusiveness of the experiments of Nathorst has been stoutly denied by Saporta, whose various species of *Eopteris* have also been declared by some malcontents to be no better than mineral crystallisations.

of accurately gauging. This upheaval, it has been suggested, may have given rise to the tilting and other evidences of unconformity, which we have already noticed, between the two sections of the Silurian system. At that period the Longmynd and Shelve Hills were islands, around the base of which the beach beds of the Upper Llandovery were forming, until the gradually sinking land got buried under the deposits of the Upper Silurian formed by the erosion to which the risen land had been subject. The character of the other land surfaces, which had commenced to appear before the beginning of the Upper Silurian Age, is indicated by the different kinds of rocks which were formed by their erosion, for we know that one rock is made out of the wearings of an older one, and that it is essential for the formation of sedimentary strata of any great thickness that the bottom on which they are deposited must be gradually sinking after the manner in which we know a great part of the modern world is constantly doing.

For instance, there is every evidence that the most extensive area of dry land—the land from which much of the material from which the limestones, shales, sandstones, and grits come—was to the north-west. "That part of the mountain region of North Wales between Conway and Cader Idris," Sir Andrew Ramsay believes, "then formed land (very different from its present form) which in some degree contributed locally to make these strata by the waste of the felspathic lavas and ashes that form such a distinguishing feature of the Lower Silurian rocks. From east to west and from north to south the coarser gritty beds gradually disappear the farther we recede from the larger centres of these volcanic rocks."

Between the close of the Lower Silurian and the beginning of the Upper Silurian there must have been several such islands in what was then the British archipelago. One of these has been indicated. The Malvern Hills was the central ridge of another, Anglesey and Carnarvon formed a third, South Wales was most probably a fourth, and Mr. Browne* suggests that one land connection may have existed between St. George's Channel and the east of Ireland, the entire tract forming one extensive area about the sea. This, again, was connected with the Silurian island, which ran from the north-west of the country to a south-westerly direction, through Scotland and the north of Ireland, and, it is not improbable, may have connected Norway with what was thus one of the earliest indications of the British Islands. Southward a few isles indicated Belgium and France, though Wales seems to have been the peculiar Silurian country of this part of the world. Immense masses of sediment must have been worn away from the Archæan and Cambrian beds to form formations so thick as many of the Silurian ones are. The Wenlock and Aymestrey limestones indicate a period of great depression. The succeeding groups are in proof of the seas round the Silurian Isles getting shallower and shallower.

The wide range of the Silurian species affords evidence that at that period an equal temperature extended over a large area of the world now widely different in climate. Many of the Arctic and English species are the same, and we have seen (p. 72) that the same may be said of some of the European and American Silurian forms. From the remote reaches of Grinnell Land and Greenland forms have been brought† identical with those entombed in strata of the same age in England,‡ though, of course, some of them may have been migratory forms, since the presence of travelled gneiss and other blocks

* "Historical Geology," p. 134. In this treatise, as well as in that of Professor James Geikie, will be found excellent *résumés* of the physical geography of the different epochs, which may be safely accepted as embodying the latest views.

† Chiefly by Major Fielden, one of the naturalists of the *Alert* during the Arctic Expedition of 1875-6. The collection is described by Mr. Etheridge, Sen., in the *Quarterly Journal of the Geological Society*, Vol. XXXIV., pp. 568–639.

‡ Thus, the Zoogeographical regions were during Silurian times, as they were before and generally subsequently, what Mojsisovics has called "heterotopical;" indeed, it is only when we approach our own period that the ancient and the modern faunas become at all "isotopical" (p. 38).

in the Lower Silurian of Scotland and of the Lake Superior region has been held to point to the presence either of floating ice or of glaciers creeping through the Lower Silurian valleys.

But whatever may have been the conditions under which these ancient rocks were deposited, they were unquestionably subjected to much disturbance and metamorphism subsequently—facts which are easily determined not only by the structure of the rocks themselves but by the twisted and otherwise altered state of the fossils found in them.

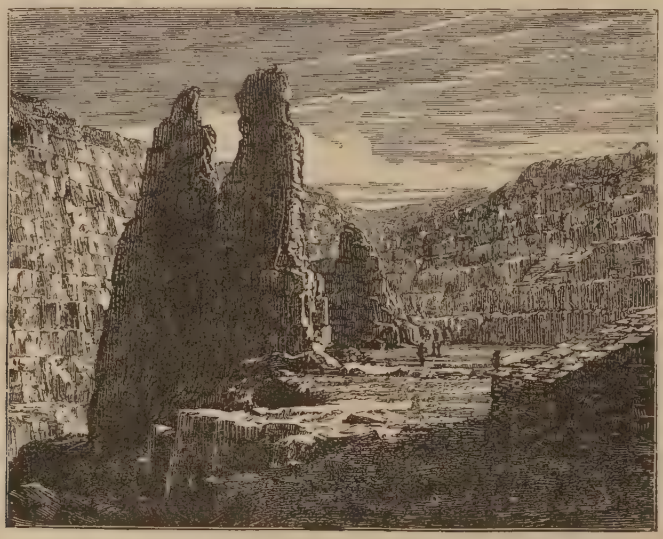


Fig. 56.—PENRHYN SLATE QUARRY, NEAR BANGOR, WALES.

(After H. B. Woodward. From a Photograph.)

Economic and Scenic Characteristics.—From an economic standpoint Silurian strata are much the same as their immediate predecessors. Mineral veins are abundant, though it is a mistake to suppose, as was at one time done, that gold quartz was chiefly, far less exclusively, found in beds of that age. In California, for example, the greatest reefs in the world are in strata of comparatively recent date, Secondary, not Palæozoic at all. Salt deposits, and even seams of anthracite, are also among their contributions to the world's wealth, while the vast slate quarries worked in them are the result of the pressure which the clay layers have undergone during the process of metamorphism (Fig. 56), chiefly by the intrusion of eruptive rocks. In like manner Silurian scenery resembles that of the Cambrian districts. When, as in Russia, they have not been disturbed the beds form the floor of great plains, while in regions where they have been upheaved, the Silurian slates, schists, quartzites, and marbles give rise to a varied and picturesque outline, bold and full of abrupt cliffs, peaks, and gorges, when the rocks are highly metamorphosed and hard, softer when the schists, being less altered, crumble into rounded knolls and wavy valleys. Esthonia is a type of the one region, North Wales and Cumberland of the other.

DEVONIAN SYSTEM.

Between the Silurian and Carboniferous systems lies an extensive series of rocks, which have been named the Devonian or Old Red Sandstone. The first term has been suggested by the fact that the system

is well developed in the English county of Devon in the shape of "greenish slates alternating with sandstones, conglomerates, and well-developed bands of blue crystalline and calcareous slates." The Old Red Sandstone is, on the other hand, more especially a Scottish formation, though also found in other parts of the kingdom (in Wales and Ireland, it contains, being mainly of terrestrial or fresh-water origin. What is more, the peculiar fossils of the Old Red Sandstone proper are not found in the Devonshire rocks which we term Devonian; while those of the latter do not occur in the strata to which the term Old Red has been applied, though they do in the equivalent strata of the Continent (Fig. 57).

Fig. 57.—IDEAL LANDSCAPE IN THE DEVONIAN AGE.

for example, and, among other countries, in Canada). As its name indicates, it is distinguished by the prevalence of beds of red, yellowish, grey, or white sandstones, in addition to conglomerates, flagstones, limestones, and other rocks. For convenience' sake, the Devonian of the south and the Old Red Sandstone of the north are considered contemporary formations, though the conditions under which they were laid down were different. The Devonian is, for instance, an essentially marine system, while the Old Red Sandstone is equally marked by the fossils which

Accordingly, when we term the system under description as the Devonian *or* Old Red Sandstone, the reader will understand that we do so provisionally and with the limits mentioned. The name is a general one only. The one series is not the full equivalent of the other, and it is certain that the two represent different geographical areas during the age succeeding the close of the Silurian. The transition from this period to that following it is not marked by any unconformability. There are indeed places where a gradual passage from one to the

other can be traced; these linking beds contain fossils common to the two systems. In Scotland sections are often exposed which show an uninterrupted series of beds from the Ludlow to the lowest strata of the Carboniferous overhead. In the Silurian country of Wales, also, there is a series of red sandstones and marls overlying the Ludlow group, and graduating without a break into the Carboniferous Limestone. This, in all likelihood, represents the Old Red Sandstone, though as these 10,000 or 11,000 feet of beds are almost barren of fossils it is impossible to be quite certain. But wherever the Devonian proper is developed in perfection, the Upper Silurian beds are so conjoined with them, that some geologists—the late Professor Jukes, for example—have not hesitated to solve the problem by throwing all the Devonian formations into the Lower Carboniferous, while others would prepare us for expecting some of those beds which in England go by that name to be the equivalent of "Stage H" of the Bohemian Basin (Fig. 47). If, however, we accept the former solution, the Devonian would be above the Old Red Sandstone proper, which would therefore be the sole representative of the interval between the Silurian and the Carboniferous; while in the latter it would be the lowest member of the two-sided system. For the present, however, it would be better to regard the Devonian and the Old Red Sandstone as simply two portions of the same system more or less synchronous, but with different characteristics due to the physical geography of the areas in which they were deposited being different. In other words, the Devonian was laid down in the sea; the Old Red in a series of lake-like basins which were either fresh water or brackish throughout the greater part of their extent.

(I.) **Devonian.**—This division of the conjoint system is, as we have learned, best exhibited in Devon, Somerset, and Cornwall. The beds are, however, well developed in Europe (*see* Map), where they occupy a large area in Normandy and Languedoc, in Spain and Portugal, the Ardennes, the south of Belgium, and Rhenish Prussia as far as Darmstadt. In the Eifel they are seen to perfection, the fields about the picturesque village of Gerolstein being littered with the characteristic shells and corals of the formation, which consists for the most part of a great thickness of limestone and dark grey sands or shaly rocks. Below Bingen, the Rhine has cut gorges through the Devonian, while the picturesque cañon-like glens through which the Moselle flows below Treves are hewn out of the same formation (Fig. 58). In Northern Russia there are extensive Devonian beds lying like the Silurian underneath in undisturbed layers, and as they again crop up on the sides of the Oural Mountains the chances are in favour of these rocks extending deeper down across the entire intervening stretch of country. And in this section of Europe the two divisions of the system under description appear to be more closely in conjunction than in any other part of the world, since in an area of Russia, larger than that occupied by the entire British islands, the marine limestones of the Devonian interstratify with the sandstones and shales of the Old Red Sandstone, containing their characteristic fossils. To a degree less pronounced, the same facts hold true of part of the system as developed in Belgium, and here and there an Old Red fish appears hard by a Devonian mollusc in the Eifel Limestones.

The Devonian also appears in North America, in the State of New York, the Appalachian region, and the Mississippi Basin, while the Old Red is confined to Nova Scotia and New Brunswick. How much of Asia is occupied by the formation cannot even be conjectured. However, it appears near the Bosphorus, and is developed in thick beds in south-western China. It also crops up in Australia and New Zealand, and has been detected at the Cape of Good Hope, so that the Devonian world, if patchy compared with the realms which succeeded it, was an area as widely spread as many of them.

The following brief synopsis exhibits the threefold classification of the English Devonian, and the principal formations which are

regarded as their equivalents in other parts of the world:—

(1) *Lower Devonian.*—The Lynton group, as exhibited in the slates, with limestone and sandstone bands at Lynton or other parts of Devonshire and the Foreland grits; the Coblentz grauwacke, clay slates, and sandstones, including the so-called Spirifer sandstone, with *Spirifer paradoxus* or *macropterus*, *Hysterolithes* ("the steinkern" of the country folk), and other brachiopods (Fig. 59), the Ahr group—grauwacke shales, with *Chonetes sarcinulata*, *Murchisonia bilineata* (Fig. 59), *Spirifer speciosus*, etc.—and the Upper Grauwacke and shales (the "Vichter-Schichten"); the Wissenbach Slates of Nassau, etc., which contain a mixture of the characteristic fossils not only of this division but of that which follows, the groups mentioned lying in the order in which they have been named. In Belgium the Gedinnien beds are their equivalents; in Russia the Lower Devonian is represented by the sandstones and clays of North Livonia, which, however, contain fish remains identical with those of the Caithness flags, and are, therefore, as much Old Red Sandstone as Devonian. In other districts the division seems more clearly synchronised by certain red and green limestones and marls, though even they contain a mixture of Middle Devonian fossils; in North America the Corniferous or Upper Heidelberg group, comprising the Cauda-Galli grit, and the Schoharie grit of New York State, represent in a well-developed form this division of the Devonian. It abounds in traces of terrestrial plants (*Psilophyton* [Fig. 60], *Caulopteris, etc.*), brachiopods, trilobites, and corals, which almost make up the entire mass of the Corniferous Limestone. In this group also fishes appear for the first time in America.

(2) *Middle Devonian.*—In England this consists for the most part of unfossiliferous slates (such as those of Lee Bay and Morte Hoe). These pass downward into other slates containing fossils, and are intercalated with beds of limestone (*e.g.*, at Plymouth, Torquay, and Ilfracombe), while the lowest members of the division are the red, purplish, or green sandstones, grits, and conglomerates of Hangman Hill. In Germany their nearest equivalents are the Eifel Limestone, the Calceola Beds (with *Calceola sandalina*), and the Stringocephalus Limestone (with *Stringocephalus burtini* (Fig. 59, 6). It is seen to perfection with all its characteristic fossils at Gerolstein and Pelm in the Eifel, at Bensberg and Passrath in the vicinity of Cologne, and in other places in the district between Aix-la-Chapelle and Treves;* the Givetian and Frasnien are their Belgian equivalents. In Russia the Middle Devonian is represented by limestones, clays, marls, etc., which, while containing various characteristic fossils of the group, also hold some of the most notable of the Old Red Sandstone division, the great fish, *Holyptychius nobilissimus*, in particular. In America this division does not seem to be represented.

(3) *Upper Devonian.*—The Lower beds of this division consist mainly of hard grey or reddish sandstones and flags (as Dulverton,

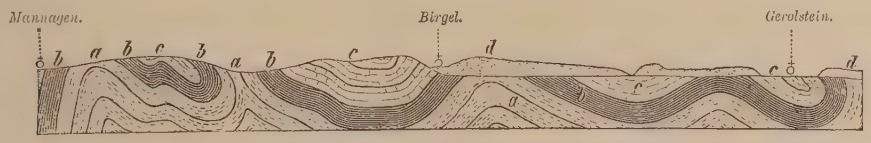


Fig. 58.—SECTION ACROSS THE EIFEL IN PRUSSIA.

a, The Lower Devonian "Grauwacke" (p. 66); *b*, The Lower Devonian Slates; *c*, The Eifel Limestone (Middle Devonian); *d*, The Bunter Sandstone (Triassic).

* Many of the corals from the rocks of this region—the fruits of a summer excursion made by Professor Alleyne Nicholson, in which the present writer was privileged to join—are described and figured in the works of that distinguished palæontologist already mentioned (p. 14).

Morte Bay, and Pickwell Down), which are overlaid by brown and yellow sandstones (Baggy Point), which again pass up into the calcareous grey and brown slates, with seams of impure limestone, of the neighbourhood of Pilton. In Germany it is represented by the Goniatites shales of Büdesheim in the Eifel, which contain numbers of *Goniatites retrorsus* (Fig. 59, 9), the Nieren Limestone and Kramenzelstein * of Westphalia the Hamilton group, comprising the Marcellus, Hamilton, and Genesee series; the Chemung group, comprising the Portage and Chemung series; and the Catskill sandstone group—are the chief equivalents of the formation named. In the Hamilton group the earliest American *Goniatites* occurs, and from the black shales of the same formation in Ohio a gigantic fish (*Dinicthys*) has been disinterred. It is, however, doubtful whether

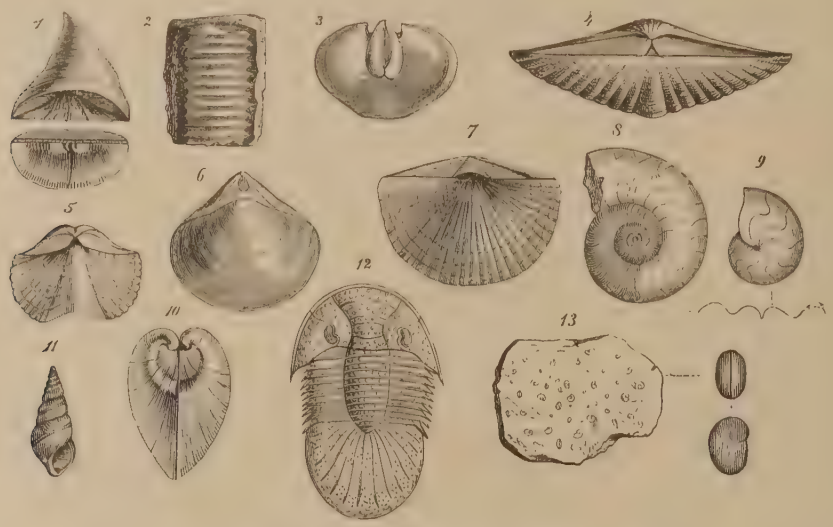


Fig. 59.—GROUP OF DEVONIAN FOSSILS.

1, Calceola sandalina, the so-called "Pantoffelmuschel," actually a coral; 2, Cyathocrinus (the "Schraubenstein" of the peasants); 3, Hysterolithes vulvarius (the "steinkern"); 4, Spirifer speciosus; 5, Spirifer ostiolatus; 6, Stringocephalus burtini; 7, Orthis umbraculum; 8, Clymenia undulata; 9, Goniatites retrorsus; 10, Megalodon cucullatus; 11, Murchisonia bilineata; 12, Bronteus flabellifer; 13, Cypridina (Entomis) serrato-striata.

and Nassau (with *Goniatites intumescens*), the Clymenia Limestone of Warstein in Westphalia and of Guttendorf near Hof in the Fichtelgebirge (with *Clymenia undulata*), and the Cypridina shales of Nassau and the Harz (with *Cypridina serrato-striata* Fig. 59, 13); Gosselet puts the Psammites du Condros and the Famennien of Belgium in this group. In Russia the beds supposed to represent the Upper Devonian are full of Old Red fossils mingled with those of the division under notice. In North America these beds are the exact equivalents of the English and Continental ones classed with them, or more nearly allied to the Old Red proper. They are placed here more for convenience' sake than from any firm belief in their right to permanently remain.

(II.) **Old Red Sandstone.**—Like the other division of the system, the "Old Red" is capable of being divided into three groups. However, the middle member of this series, the separation of which from the others we owe to the researches of Murchison, is found only in the north of Scotland, so that the classification usually adopted rests not so much on the sequence of the strata as on

* "Kramenzel" is a Westphalian term for an ant; these insects harbouring in the pores and holes with which this nodular crumbling rock is honey-combed.

inferences derivable from the contained fossils. Indeed, some geologists have reduced the component members of the Old Red Sandstone to two. For convenience' sake, however, we may keep to the threefold classification of the beds, which more than any that we have hitherto studied belong to the British Islands.

(1) *The Lower Old Red.*—This consists of red and purplish sandstones, grey flagstones, and conglomerates, containing large crustaceans of the strange family of Eurypteridæ, and fishes like *Cephalaspis* and *Pteraspis*. The Arbroath flags form a good example of these beds, which rest without any break or unconformability upon the upper ones of the Silurian. The Upper Silurian, indeed, graduates into them by a series of "passage beds" containing the gigantic crustaceans mentioned. In addition to various animal remains this division contains plants, and in Lanarkshire a thin layer of shale in this group has been found to contain a graptolite and two other Upper Silurian fossils. The Dingle Beds and Glengariff Grits of Ireland are Lower Old Red. The Welsh Lower Old Red covers the area drained by the Usk and the Wye.

(2) *The Middle Old Red.**—This consists of calcareous and bituminous flagstones, limestones, and red sandstones and conglomerates, with shales having irregular calcareous nodules embedded in them. The Caithness Flags, containing *Dipterus, Asterolepis, Acanthodes, Pterichthys, Coccosteus* (Figs. 61, 62), etc., are the most characteristic members of the series, though a crustacean and a few plants are also found in connection with them. Altogether, the Old Red of the north of Scotland has yielded over sixty species of fishes.

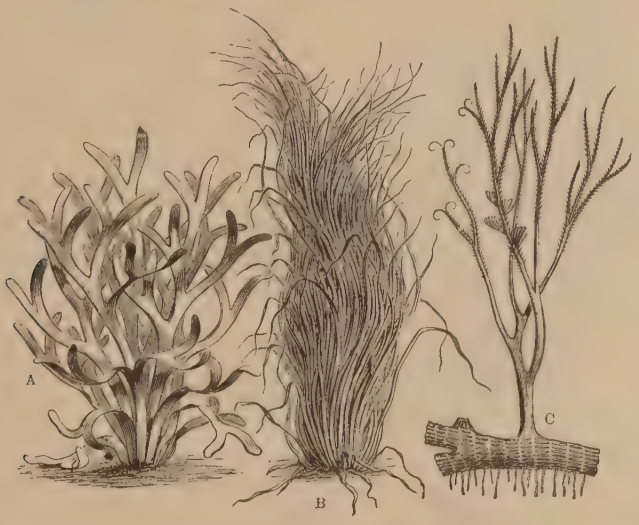


Fig. 60.—REPRODUCTIONS OF DEVONIAN PLANTS.
A, Fucoids (sea-weeds); B, Zosterites (plant allied to the modern Zostera, or sea-grass); C, Psilophyton princeps.

(3) *The Upper Old Red Sandstone.*—This consists in Scotland mainly of conglomerates, sandstones, and shales, and, in addition to many fishes, such as *Pterichthys major, Holoptychius nobilissimus,* etc., contains some land plants and fragments of what might have been seaweeds (Fig. 60). The Dura Den Beds of Forfarshire are the finest type of this division. Most of the strata are unfossiliferous. Among them are the conglomerates

* Dr. Archibald Geikie denies that there is any Middle division, being of opinion that the distinction between the Caithness and Arbroath flags is by no means so marked as Murchison supposed, and that the former ought really to be classed with the latter in the Lower Old Red Sandstone.

and breccias which are found in the Lammermuir and Cheviots. This division passes quite conformably into the Carboniferous system above it; indeed, in the Island of Arran in Scotland there is a limestone in it full of marine carboniferous animals. The Red conglomerates and sandstones of Flintshire and Anglesea may be members of this division, while various sandstones, shales, and limestones in Devonshire (at Barnstaple, for example), containing land plants and marine fossils, some of which are carboniferous, may be classed as the southern equivalents of this division. The Kerry Red Sandstones are possibly Upper Old Red, while the Kiltorcan beds, which pass up conformably into the Carboniferous Slate, and contain fishes, fresh-water mussels, ferns, and other land plants, are unquestionably to be referred to this period.*

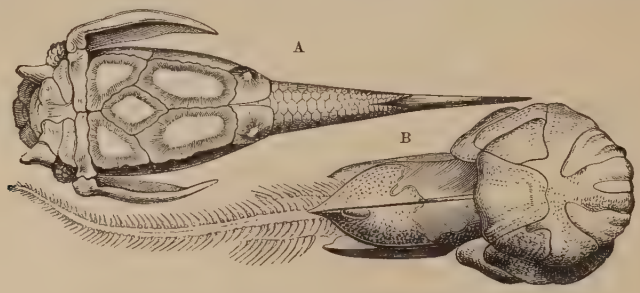


Fig. 61.—FISHES FROM THE OLD RED SANDSTONE OF SCOTLAND.
A, Pterichthys cornutus (under side); B, Coccosteus decipiens (upper side).

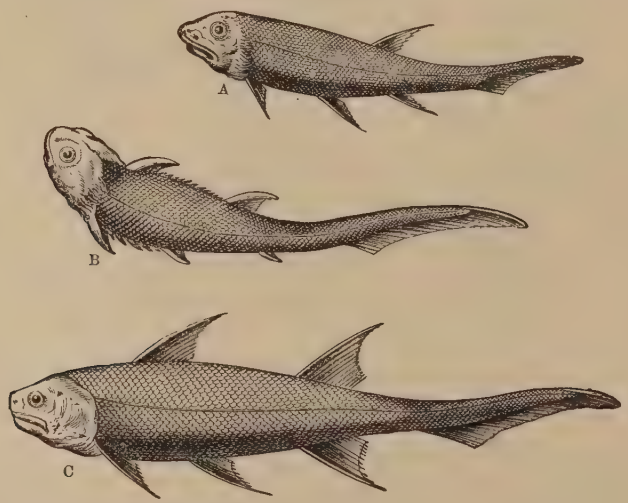


Fig. 62.—FISHES (RESTORED) FROM THE OLD RED SANDSTONE.
A, Acanthodes mitchelli; B, Climatius scutiger; C, Diplacanthus gracilis.

What has already been said regarding the

* Between the Lower and Upper series of the Old Red Sandstone there is a marked unconformity. Possibly only a portion of the Upper Beds are of the date to which they are usually attributed. At all events, before the age to which they belonged had ended, the peculiar fauna of the Carboniferous period had begun to obtrude itself into the Old Red basins, since in a thin seam of limestone in the beds mentioned, there are such well-known

Devonian in Russia and America renders it unnecessary to collate the members of the system found there. Indeed, in the exact type in which we see the Old Red Sandstone in Scotland, it is scarcely known out of our islands. A few outlying patches are seen in Norway, though as they have not yet yielded fossils their horizon or even their identity is doubtful, and it is not impossible that some of the Arctic Beds at Bear Island, which have been assigned to the Carboniferous age, may belong to the upper division of this period. The Hekla-Hook formation of Spitzbergen is also another of the probable outliers of the Scottish Old Red Sandstone.

Life of the Period.—The Devonian and Old Red Sandstone Age, it will have been seen, was one during which life was exuberant. Some forms which were abundant in preceding ages have died out; others have become scarce, but their places have been taken by vast numbers of new species. *Receptaculites* and *Stromatopera* still continue to represent the lowest order of animals, not in the same forms as during the Silurian, but in new ones of great size and extraordinary abundance. Corals are equally numerous, while the star-fishes and sea-urchins of the Devonian age were as varied in form as they were abundant in individuals. The Cystideans of the Silurian age have, however, vanished, and their place is taken by *Pentremites*, an allied group of the same family. Trilobites are still plentiful, and the tube-forming worms are well represented by *Spirorbis*. Crustaceans of many and peculiar species now make their appearance, particularly the Eurypterids (an extinct sub-order related to the modern King-Crabs) of the Old Red Sandstone, one of which, *Pterygotus anglicus*, must have been five or six feet in length. Brachiopoda abound, with winged Spirifers, the *Stringocephalus*, etc., while spirally-coiled cuttle-fishes living in shells, like *Clymenia* and *Goniatites*, now appear among the straight ones like Orthoceras, which we met in previous ages (Fig. 63). But of all the aquatic animals of the Devonian and Old Red Sandstone Age, the fishes were the most remarkable. It was emphatically the Age of Fishes. They swarmed in the Old Red Sandstone of Scotland, and nearly all of them belonged to the Ganoids, or species with enamelled bony scales, like the *Lepidosteus* of the warmer rivers of America (Fig. 64), and the *Polypterus* of Africa. These, indeed, are, with the exception of

Fig. 63.—CLYMENIA SEDGWICKII.

the sturgeon and a few other species, the only representatives of the fishes with horny or bony plates which have survived to other times. But during the Devonian Age the Ganoids * were almost the only fishes which swarmed in the sea. At all events, they are the ones which have been best preserved in the rocks. Not only were these Old Red Sandstone fishes of numerous species, but they were so abundant that specimens in a more or less perfect condition may be noticed on almost every other flagstone in some of the Caithness and Orkney quarries, or in the sandstones of Dura Den. Among these

Carboniferous fossils as the splendid fern known as *Palæopteris hibernica*, the fronds of which were sometimes two feet in breadth, etc.

* Greek *ganos*, splendour, *eidos*, likeness. Agassiz constituted them one of his four great orders of fishes, each distinguished by its form of scales. The other three were the *Placoids* (the sharks, and all other cartilaginous boned fishes, except the sturgeon), the *Ctenoids*, with scales jagged on their posterior edges, like those of the perch, and the *Cycloids*, in which the scales are rounded at the margin, like those of the herring. This classification, though very arbitrary, is useful in geology, and still sometimes employed.

were the *Osteolepis*, the *Pterichthys*, the horned or winged fish, with its great pectoral fins (Fig. 61, A), the curious *Coccosteus** (Fig. 61, B), with its cranial buckler and body covered with berry-like tubercles, the *Holoptychius*, which must have been from eight to twelve feet in length, the *Cephalaspis*, which had the bones of its head united into a single shield-like case, which gives it when seen from below the appearance of an Eskimo woman's or a saddler's crescentic knife, and the *Dinichthys* of America (p. 80), the armoured head of which was three feet long. These fishes must have been the tyrants of the Devonian seas, for not only were they numerous in species, large in size, and protected from enemies by their bony armature, but they were abundant in individuals. That they had powerful enemies is, nevertheless, rendered probable by the crushing teeth, and defensive spines of some other fishes being occasionally met with in the same beds as those containing the fossils mentioned.

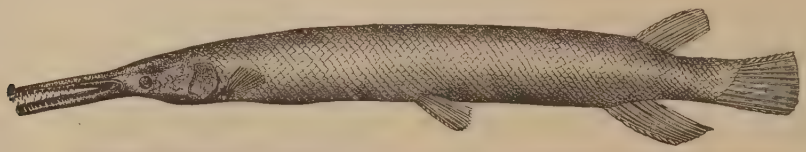


Fig. 64.—LEPIDOSTEUS SPATULA, THE GARPIKE OF AMERICA, A MODERN REPRESENTATIVE OF THE GANOID FISHES.

Plants were, however, not wanting to this age of the Earth's history. The seaweed-like markings point to what was almost a foregone conclusion—the existence of marine vegetation. But in the Old Red Sandstone —especially in the Nova Scotian and New Brunswick beds — tree ferns, great club mosses, gigantic horse-tails, allied to our *Equisetum*, and other species of ferns and fern allies appear. Huge coniferous trees are also shown to have existed, and, in the forests which they formed, an insect (*Platephemera*) belonging to the dragon-fly order, and so large that it had a wing-spread of five inches, is known to have sported in the woods. And no doubt other forms existed in these umbrageous forests, where the vegetation was so dense as to have formed in places thin seams of coal.

Physical Characteristics of the Period.—These we have partially indicated. The Devonian division of the system is marine: the Old Red Sandstone section mainly, and in some places entirely, fresh water. It is, therefore, probable that during the time the first-named strata were being laid down the sea had free access to the area of their deposition. On the other hand, the Old Red would appear to have been laid down in a series of more or less land-locked basins, large lakes or inland seas, the outlines of which can be traced by the rocks formed in them. This idea, first suggested by Mr. Godwin-Austen, has been fully elaborated by Sir Andrew Ramsay, Dr. Archibald Geikie, and Professor Hull, who have indicated a number of these basins by names which, like Lakes Orcadie, Cheviot, Lorne, Caledonia, and the Irish Lake Fanad, indicate the areas which they appear to have occupied. The amount of dry land during this period was evidently greater than in the preceding ages, though—as is shown by the interbedded lavas and tuffs of South Devon, Cornwall, the Sidlaws, Ochils, Pentlands, Cheviots, Shetlands, etc., and the sheets of basalt (diabase), with volcanic breccias and tuffs, which are intercalated among the Devonian beds of Dillenburg and Weilburg in Nassau, and of various spots in the Fichtelgebirge—the Age could not have been undisturbed by subterranean eruptions. Most of these outbursts were submarine, or at least subaqueous, though those of the Cheviots and Sidlaw Hills were quite as evidently subaërial. Ireland, throughout most of the Devonian period, must have been united with Great

* Greek, *Kokkos*, a berry ; and *osteon*, a bone.

Britain, if, indeed, Lake Caledonia did not extend into the former region. During the long Devonian era there were many fluctuations in the amount of land and water, though, on the whole, the earlier ages of the system had the preponderance of *terra*—more or less—*firma*. How long this epoch lasted we cannot even guess. Forms which were abundant fossils, a fact which indicates that the circumstances which led to the deposition of the oxide of iron, causing this colour, were not favourable to the existence of life.

Scenic and Economic Aspects.—In Russia and Central Europe the undisturbed Devonian beds do not furnish any picturesque scenery. But in Great Britain, or in other regions

Fig. 65.—IDEAL VIEW OF THE MARINE LIFE OF THE CARBONIFEROUS SYSTEM.

when it began vanished before it closed, and species, of which not a hint is vouchsafed in the earlier beds, are swarming before the Carboniferous Epoch opened. As was the case in Silurian times, the climate of the Devonian was mild and equable over a far greater area than at present, though Professor James Geikie and other observers suspect the action of ice in the moraine-like conglomerates, and the worn or even striated stones of the Lammermuir and other beds. It may be added that the red-coloured rocks of the Old Red Sandstone are everywhere singularly barren of where they are broken by trap eruptions, the hills thus formed, though neither so bold nor so precipitous as those of the older rocks, are often lofty and diversified. Caithness, for example, is, like Orkney and Shetland, rather flat, while the Ochils and Sidlaws are diversified in their contour. The soil due to the decomposition of these rocks varies. That formed from the flags is somewhat indifferent. On the other hand, there are many valleys in the Old Red hills famous, not only for their beauty, but for their fertility.

The economic aspects of the system are not

comparable with those of the Silurian or the Carboniferous. The flagstones which, in Forfar, Caithness, Orkney, and Shetland, are used for fencing, building, roofing, and other purposes, go to all parts of Europe for paving footpaths, kitchens, and courtyards, though of late this demand has slackened, owing to other paving material having come into favour. Limestone and building stone are supplied to a less extent, and in the traps some agates, chalcedonies, and other "Scotch pebbles" are found. The Goniatite and Clymenia Limestone of France yields the "marbre griotte." Indeed, fair marble is yielded by some of the Devonshire beds, which, like those in the vicinity of Torquay, are worked not only for building-stones but for other purposes. The igneous rocks associated with them are too hard to be of much value for the mason's purposes, though when broken they form good road metal; and the porphyries are to some extent cut and polished into vases, candlesticks, and other ornamental articles. The Salina beds (p. 70), as the name implies, yield salt in large quantities. From the brine springs of Onondago as much as seven or eight million bushels are yearly prepared, either by artificial or by natural evaporation. In Germany and England metalliferous veins traverse the Devonian. Gold, silver, iron, cinnabar (the ore of quicksilver), zinc, etc., are among the Devonian riches, while many of the most extensive reservoirs of petroleum are in Pennsylvania in rocks of this age.*

* In Hugh Miller's "Old Red Sandstone" and "Footprints of the Creator," though both works are now a little behind the day, a good popular account of the Scottish Old Red Sandstone fossils may be found. From this point of view, Anderson's "Dura Den" is also still worth reading. But out of the ever-accumulating mass of more scientific literature relating to the system, the following works and memoirs deserve especial study:—Arch. Geikie, *Transactions of the Royal Society of Edinburgh*, Vol. XXVIII.; Godwin-Austen, *Transactions of the Geological Society*, second series, Vol. VI., p. 433; Etheridge, *Quarterly Journal of the Geological Society*, 1867, p. 568; Gosselet: "Esquisse Geologique de la Belgique;" Römer: "Versteinerungen des Harzgebirges," and "Rheinisch. Uebergansgebirge;" Lossen: "Geol. Uebersichtkarte Harz" (1881); Dawson: "Acadian Geology"; B. Peach and Horne, *Trans. of the Roy. Soc. of Edin.*, Vol. XXXII., p. 359; *Quarterly Journal of the Geological Society*, Vol. XXXV., p. 778, and Vol. XXXVI., p. 648; *Proceedings of the Royal Physical Society of Edinburgh*, 1878–79, p. 80, and 1879, p. 329, and Tudor's "Orkneys and Shetland," p. 384; Hull, *Quarterly Journal of the Geological Society*, Vol. XXXIV., p. 703; for Fishes, the works of Agassiz, Powrie, and Lankester, Pander, Huxley, Newberry, and others; "Memoirs" of the Geological Survey, *passim*; etc.

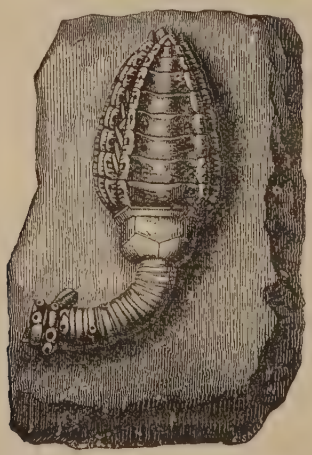


Fig. 66.—CUPRESSOCRINUS CRASSUS.

CHAPTER VI.

The Palæozoic Rocks: The Carboniferous System.

The Carboniferous System—Its General Characteristics and Area—Its Classification in Great Britain and its Equivalents in other Countries—The Carboniferous Limestone—Its Component Beds and some of its Principal Fossils—The Culm Beds—The Millstone Grit—Its Distribution and Nature—The Coal Measures—Their Characteristics—The Roofing Shales and the Underclay—Importance of the Contiguity of Coal and its associated Limestones and Ironstones—Life of the Carboniferous Age—Animals—Lower Forms—Insects—Land Shells—Fishes—Batrachian Reptiles—Description of some of the Principal Groups and the Modes in which they have been Discovered—The Labyrinthodonts—Their Forms—Their Foot-prints believed to have been those formerly ascribed to the Supposititious Cheirotherium—the Peculiar Structure of their Teeth—The Archegosaurus—The Ptyonius—The Microsauria, etc.

If there are frequent doubts as to the evidences of one system having succeeded its predecessor without the lapse of any appreciable interval of time, there can be little regarding the fact of the Carboniferous being the era which began when the Devonian closed. The one series of beds lie over the other often without the slightest break. Indeed, though unconformability is occasionally noticed, the instances in which the Upper Devonian or Old Red Sandstone, as the case may be, and the system to be presently described, graduate, lithologically and palæontologically, into each other, are much more frequent. It is called "Carboniferous,"* from the fact that it yields the largest and most important beds of coal in the Earth's crust. At the same time, the seams of coal bear a small ratio to the vast thicknesses of limestones, shales, and sandstones among which they are intercalated. Nor, as we know already (p. 56), is coal confined to the Carboniferous age. It is found in thin bands as early as the Silurian (p. 74), and some of the best known mines of America and other regions are worked in Cretaceous and even younger formations. However, the Coal Period was essentially that which is at present under consideration. It is admirably developed in Great Britain: to it, indeed, and to the ores lying in close proximity to it, much of the nation's prosperity is due. But the Carboniferous system, with or without its associated coal, is found in many other parts of the world. In Great Britain the coal fields occupy much of the middle and northern parts of England, and a considerable section of Wales. In Scotland they stretch across most of the Lowlands, and though, unfortunately, often lacking their essential portion—the coal—the Carboniferous strata of Ireland cover a very large extent of that island. The coal fields of Great Britain are, however, trifling in comparison with those of other regions, where they have been much less developed. Northern France and Belgium are underlaid by them. So are Northern Spain and Portugal, while they occur in patches over Central and Southern France, Rhenish Prussia, Saxony, Siberia, Bohemia, and Westphalia. In Russia, deep down under other formations, covering the area between Moscow and the White Sea, there are Carboniferous strata, which may be traced to Bear Island, and still farther in the Polar Basin, on the dreary shores of Novaia Semlia and Spitzbergen. Tuscany and Sardinia have Carboniferous deposits, and they appear among the varied strata of the Alps. They exist in the Altai Range, in Northern Siberia, and in the great valley drained by the Amoor. No doubt, extensive regions of China have coal-fields, compared with which those of Europe and even of America are insignificant. We know that Shan-se and Shan-tung possess deposits which are barely pecked at

* Latin *Carbo*, coal, and *fero*, I bear.

by native workmen. In Australia, the coal-fields of the Eastern border have for several years furnished the materials for a rapidly growing industry, the Newcastle of New South Wales bidding fair at some distant period to be a rival to the Tyneside city of the same name. In North America the coal-fields are so extensive, that they more than equal the area of the British Islands, their approximate extent being 169,000 square miles, while the entire superficies of the United Kingdom is under 121,000 square miles. Of this extensive tract, 18,000 square miles are in Nova Scotia and New Brunswick. All of this, it must be remembered, is Carboniferous. It does not comprise several other coal-fields in strata of later date, including those of Vancouver Island, which belong to the Cretaceous system, while those of the Canadian North-West Territory are certainly no older, and may possibly be a little newer. Nevertheless, wherever found, the Carboniferous system is much the same lithologically and palæontologically. Its rocks consist of shales, sandstones, clays, limestones, coal, and ironstones, terrestrial, marine (Fig. 65), brackish (estuarine), and fresh water, while the fossils by which it is distinguished are equally varied. Plants of all grades, except those belonging to the Dicotyledons (p. 47), are found in great profusion; while the animal remains, numerous in species and individuals, belong to every group under reptiles, the batrachian, or frog-like forms, being the highest in the scale which can be said with any certainty to occur. We are therefore justified in affirming that the Carboniferous system—though exhibiting, in its endless variations of land-surfaces and strata, which must have been formed under water, proofs of having taken a long period in accumulating—was laid down under conditions very similar, in no matter what part of the world they show themselves. This fact is all the more peculiar in so far that, from the top to the bottom of the vast thickness of beds of which they are composed, the Carboniferous rocks display throughout a remarkable similarity in their fossils. In the systems already described we have seen that the lower and the upper members of the formations were distinguished by entirely different remains; that, indeed, it was exceptional to find a fossil that ran through the entire series of rocks which made up the records of the particular period under consideration. In the Carboniferous beds, on the contrary, the same species, and even groups of species, persist through great depths of strata, the very lowest and the very highest of the marine beds being alone characterised by a few forms peculiar to themselves; and in the limestones we find a small assortment of animal forms which come under the same category. But the majority have a great vertical range, not a few of them being traceable throughout the entire series of marine beds. Accordingly, though various modifications have been made in this arrangement, it is essentially in accordance with all known facts to class the Carboniferous strata into (1), Carboniferous Limestone; (2), Millstone Grit; (3), Coal Measures; the thickness of the various formations comprised under the three great divisions named being, where they are fully developed, about 23,000 feet. The lower Carboniferous beds are essentially marine; the upper ones just as essentially fresh water, or only partly marine. The uniformity alluded to in the system renders it unnecessary for us to collate at any great length the foreign equivalents of these divisions, while in the more special treatises already noted, or which will be referred to, the local development of the groups in Great Britain and other coal-mining countries is described with the fulness which might be expected from the economic importance of the upper members of the series. It has already been noted that the lowest strata of this system lie conformably on the uppermost of those of the Old Red Sandstone; indeed, the latter passes into it in many places by a series of transition beds containing fossils common to both systems.

(1) **Carboniferous Limestone.**—This division—formerly known as the "Mountain Limestone,"* (though it is just as frequently found in valleys)—is somewhat inappropriately

* The *Kohlen Kalk* or *Berg Kalk* of the Germans.

Fig. 67.—CARBONIFEROUS LIMESTONE, MIDDLETON DALE, DERBYSHIRE.

named, since coal is one of the substances which it most seldom contains. It is also sometimes termed the Sub- or Pre-Carboniferous group. However, wherever found, it is usually the most calcareous of the entire Carboniferous series, and—except in Ireland and a few other places, where the lowest beds of this system are slates and grits containing a mixture of Devonian and Carboniferous fossils (and, therefore, transition beds)—it constitutes the base of the system. When most typically developed, it consists of great masses of limestone with a few beds of shale, or with beds of limestone, sandstone, grit, and shale alternating. In North America it is indeed composed, for the most part, of sandstones, shales, and clay-iron ore, with here and there thin beds of coal; though farther west the rocks partake more of the ordinary calcareous character of the division. In Great Britain the ordinary members of the group are the Calciferous Sandstones of Scotland and the Lower Limestone shales of England, the Main or Scaur Limestone, and the Yoredale beds, the maximum thickness of the group being about 8,000 feet. In England (Fig. 67) the chief member of the group is the marine limestone, which in places is so crammed with fossils, corals, stalked star-fishes (crinoids), shells, etc., that it may be said to be almost entirely composed of them, though in Scotland it is so intercalated with seams of shale, coal, and ironstone, and with beds of sandstone, that limestone is by no means the most prominent constituent of the series. Here, in addition to this representative of the true Carboniferous limestone of England, we have at the base of the system a considerable thickness of Calciferous sandstones, intercalated with shales, argillaceous limestones (cement stones), ordinary limestone, and thin seams of coal. This series is famous, so far as the neighbourhood of Edinburgh is concerned, for its bituminous shales, and the Burdiehouse limestone, an estuarine deposit which contains a remarkable assemblage of fossils, consisting of fishes and other species of animals and plants. It seems to be, for the most part, made up of a small ostracid crustacean (*Leperditia okeni*, var. *scoto-burdigalensis*), which may be noticed in white specks on the surface of every bit of the weathered limestone so extensively quarried for the lime-kilns. Even more familiar, as a member of this group, than the Burdiehouse limestone, is the fine white close-grained sandstone of Craigleith, of which most of the city of Edinburgh has been built. In Ireland the Carboniferous limestone is largely developed, though, as already noted, the base of the series consists of slates and grits known as the "Carboniferous Slates."

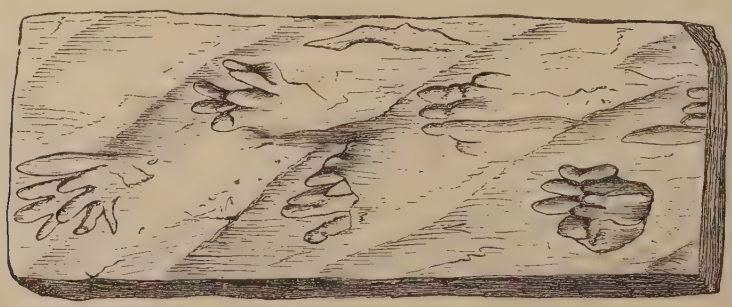


Fig. 68.—SLAB OF STONE WITH RIPPLE-MARKING, SHOWING THE FOOTPRINTS OF AN ANCIENT NEWT-LIKE ANIMAL FROM THE CARBONIFEROUS LIMESTONE SERIES OF NORTH AMERICA (ONE-EIGHTH OF THE NATURAL SIZE).

The Calciferous Sandstones are in the north of France and Belgium, as in Scotland, the base of the Carboniferous system, and are succeeded by the Carboniferous

limestone, though the horizon of the Millstone Grit is filled in by certain alum schists. In some parts of Germany—in the Saarbrück coal field, for example—the lower marine series of the Carboniferous system is wanting, as the Culm beds consist of green, grey, and black slates; sandstones, grits, and various seams and beds of limestone are regarded as ranging from the Lower Carboniferous limestone to the Lower Coal Measures, though

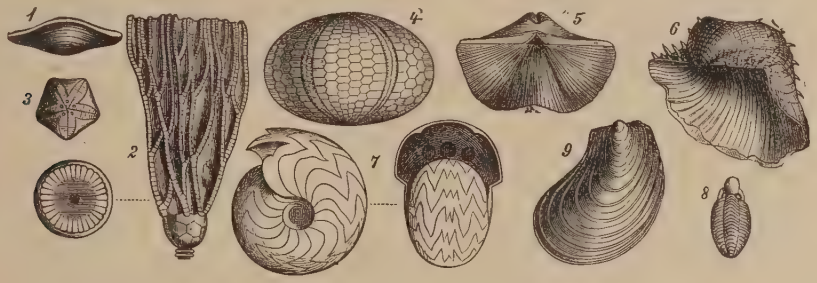


Fig. 69.—FOSSILS OF THE CARBONIFEROUS LIMESTONE AND THE CULM BEDS.

1, Fusulina cylindrica; 2, Cyathocrinus (the crown or "calyx" and a transverse section of the stalk); 3, Pentatrematites florealis (crown from above); 4, Palechinus gigas; 5, Spirifer striatus; 6, Productus semireticulatus; 7, Goniatites crenistria; 8, Phillipsia; 9, Posidonomya becheri.

the Coal Measures lying unconformably on the Devonian; though even then, according to Geinitz, the Saxon Coal Measures may be divided (according to the distribution of plants in their shales and sandstones) into three zones, each marked by a characteristic set of fossils. In North America the Carboniferous limestone series is represented by chiefly synchronous with the latter. They contain various fossils (Fig. 69), such as *Goniatites sphæricus* and *G. mixolobus*, *Orthoceras scalare*, and *Posidonomya becheri*; and, among plants, *Archæocalamites radiatus* and *Lepidoderon* (Sagenaria), *veltheimiana*, *Chonetes restispina*, *Phillipsia*, etc. In other words, the Culm beds are the sandy, shaly,

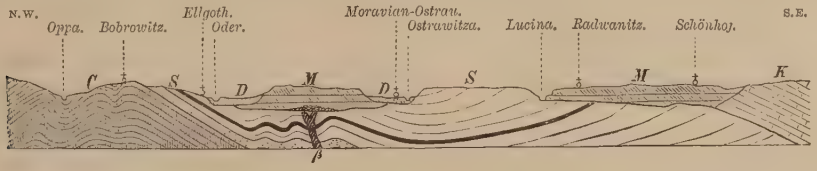


Fig. 70.—SECTION OF THE OSTRAU CARBONIFEROUS BASIN, IN AUSTRIA.

C, Culm Beds; S, Productive Coal Measures; K, Cretaceous Beds; M, Miocene; β, Basalt; D, Superficial Diluvium.

the Kinderhook, Keokuk, St. Louis, and Chester groups, nearly all of which are marine limestones; though here and there remains of the ordinary terrestrial vegetation of the period may be noticed, and in some of the beds pitted with rain-drops and with the wavy ripples of the ancient tides or shore-waves have been detected the footprints of the earliest amphibians known in America (Fig. 68). What in Devonshire are known and sometimes coal-bearing representatives of the Carboniferous limestone. In Germany (Fig. 70) they are represented by a zone of beds abounding in *Sagenaria veltheimiana*, *Sphenopteris distans*, and other plants, and by the shales, grauwackes, sandstones, and conglomerates of various parts of Westphalia, Nassau, the Harz, and elsewhere, in which the flora mentioned is mingled with such Carboniferous limestone molluscs as

Productus semireticulatus, Goniatites crenistria, and *Posidonomya becheri,* which is the characteristic fossil of certain dark shales known as the Posidonomya schists (Fig. 69, 9).

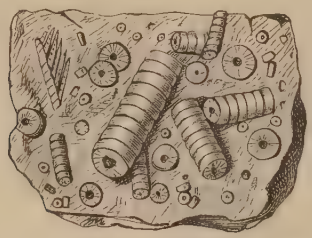


Fig. 71.—SMALL PIECE OF LIMESTONE SHOWING NUMEROUS FRAGMENTS OF CRINOIDS ON ITS WEATHERED SURFACE.

The Carboniferous limestone group is, however, essentially a marine one, and so crowded with sea animals that many pieces of limestone seem to be composed of nothing else (Figs. 71, 72).

The Carboniferous Limestone — especially

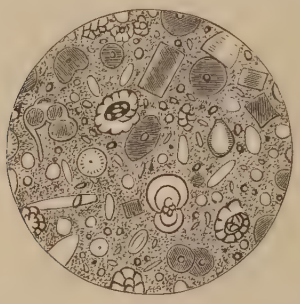


Fig. 72.—PART OF A THIN SLICE OF CARBONIFEROUS LIMESTONE, SHOWING THAT THE ROCK IS ALMOST WHOLLY MADE UP OF ANIMAL REMAINS.

the loftier portion of it which merits its old name of Mountain Limestone—is notable for the caves and grottoes which it contains (Vol. I., pp. 66, 277). Those of Derbyshire, Devon, Somerset, and various parts of Ireland, may be mentioned as among these, while the Grottoes of Antiparos in Greece, and of Adelsberg in Syria, and Weyen Cave in the United States, may be cited, among others, as good examples of the caverns in which the stalactites forming the roof and the stalagmites forming the floor, unite to form pillars.

(2) **Millstone Grit.**—Usually conformable, though sometimes unconformable, to the series just described, come the sandy and gritty beds, which, from the fact that millstones have for long been hewn out of the rocks composing them, are known as the Millstone Grit. The typical formation is made up of quartzose sandstones, extremely hard, and of other grains so large that they are sometimes as big as little pebbles, and the rocks really a conglomerate. Limestones, shales, thin beds of coal, and conglomerates of the ordinary character, are also present in some places, though, as a rule, the Millstone Grit is so deficient in the chief economic product of the Carboniferous system that the Welsh miners term it the "Farewell Rock," knowing that when they reach it they may abandon all hope of penetrating lower down a workable seam of coal.* The group varies in thickness from 300 feet to nearly 5,000 feet, though, as a rule, it is much thinner. In Scotland, the "Moor Rock" —to use a local term for it—seldom exceeds 400 feet, and is chiefly notable for the fireclays and irregular beds of limestone which it contains. However, it is nowhere distinguished by any peculiar fossils, the few which have been detected in it being either identical with the species in the Coal Measure above, or in the Carboniferous Limestone below. On the Continent the Millstone Grit is poorly developed. It may be detected in the quartzites and conglomerates of Liége and Aix-la-Chapelle, while in North America its equivalents must be sought for in the sandstones and conglomerates, with occasional coal seams, of some parts of Pennsylvania and New York.

(3) **Coal Measures.**†—This important group of the Carboniferous system derives its name from the circumstance that in it are found those workable beds of coal which give the strata of which it forms a part their principal economic value. They succeed the Millstone Grit conformably, and though coal forms the

* In Scotland, however, workable coal seams occur below the horizon of the Millstone grit.

† *Terrain houiller* of the French; the *Flötzführende* or *Kohlengebirge* of the Germans.

most marketable member of the series, it is by no means the thickest, shales, grits, sandstones, etc., forming in nearly every place where they are developed the greater portion of the 2,000 feet to 15,000 feet to which they extend. The general uniformity of composition exhibited by the Coal Measures in all parts of the world has already been noticed. Wherever found, no matter how the particular sequence may differ, they invariably consist of dark, laminated, earthy shales, and sandstones of various colours,* though rarely red, among which are intercalated beds of limestone, clay, or "black band" ironstones, and coal of various thicknesses. There is no established order in which these various layers alternate. Sometimes they follow in one sequence, and a few miles away in an entirely different one. They are also often repeated over and over again, so that the basins in which the coal-fields lie must have been subjected to frequent oscillations to permit of the exposure of the various land-surfaces, and the deposition of the numerous beds which alternate with them. In the Ostrau coal-field (Fig. 70) there are, for instance, 370 distinct seams of coal. Now, as coal is composed of the remains of land plants, each of these beds is the proof of a land-surface, with an interval of submergence between them, during which the shales, sandstones, and limestones intervening were deposited from the overlying sea, fresh water, or estuary. That the coal plants were not drift vegetation is proved first, by the perfect condition in which the greater number of them have been preserved; and next, by the fact that the roots of the great tree ferns penetrate the "under-clay" or "floor" of the coal, as the sandy clay or shale under the seam is called: while in the black shale forming the "roof" of the pit there are found the twigs, stems, and leaves of the plants, flattened, of course, by the enormous pressure which they have sustained during former ages (Fig. 73). The contiguity of these shales, limestones, coal beds, and ironstone seams is of immense

Fig. 73.—IDEAL LANDSCAPE OF THE COAL MEASURES.

(The trees to the right and left are Lepidodendra: that in the middle is a Calamite.)

* These sandstones are sometimes mottled, though usually white and yellow. In Lancashire and Scotland (where they attain a thickness of 700 feet), red sandstones are present in the Coal Measures.

importance; for the coal enables the iron ore to be smelted cheaply, while the limestone is useful as a flux to promote the speedy reduction of the ore. As for the oil shales, they have yielded to distillation paraffin and other products, though the discovery and immense development of the petroleum deposits of America and the Caspian country have rendered them no longer of the same commercial importance as before (Fig. 73).

Life of the Carboniferous Age.—*Animals.*—The Carboniferous rocks, with perhaps the exception of the Millstone Grit, swarm with the remains of plants and animals which existed in the waters of the age when they were deposited, or of the plants which grew in dense masses on the danky shores of the rivers, lakes, and seas of that distant epoch in the world's history. The persistency of the species all through the Carboniferous period has already been noticed (p. 88). Yet the species are many, and the individuals so abundant, that some of them make up almost the entire mass of some of the Carboniferous limestones. The encrinites or stalked star-fish, allied to the rare Rhizocrini of modern seas (Figs. 65, 74), were, for example, so numerous, that their weathered forms may be seen on almost any piece of limestone (Fig. 71), while the "joints" of the stems form the "sea-born beads" scattered along the Carboniferous shores of Northumberland, and which every reader of "Marmion" will remember were fabled to have been the work of St. Cuthbert, whose name they bear. (Figs. 66, 69, 71.)

But these animals, plentiful though they were, constituted only a small portion of the teeming life of which we find the remains in the Carboniferous rocks. Foraminifera were, indeed, so abundant that the Fusulina limestone (Fig. 69, 1) is composed of them, while corals, some of which did not survive the age of the Carboniferous limestone, were almost as numerous as encrinites.

Favosites, Cyathophyllum, Heliolites, and many other genera, above all *Lithostrotion,** enter into the constituents of some of these rocks almost as plentifully as the encrinites and the silicious spiculæ or skeletons of ancient sponges do. Of the Echinodermata the crinoids (Fig. 69, 2, 3, 4) are the most abundant, almost any fragment of carboniferous limestone displaying portions of one or more species in great plenty; but, with the exception of *Spirorbis,* worms are not very numerous, or at least many representatives of the class have not descended to us. Crustacea are by no means infrequent, though most of them belong to the Ostracoda and Phyllopoda, the first of which are in our day represented by minute forms having the entire body cased in a shell, and swarming in fresh, brackish, or salt water; while the Phyllopoda are, for the most part, inhabitants of fresh water; though others — like *Nebalia*—live in the sea or—like the brine crustacean (*Artemia*)—in water more than usually salt. The trilobites have, however, waned in number, and appear to die out in the Carboniferous Age, *Phillipsia* being one of the last of the genera; while the Eurypterids (p. 81) give way to crustacea akin to our ordinary lobsters, and the king-crab family, or at least that most nearly related to it (the *Xiphosura*), now begin to appear in numbers. Many Mollusca and Polyzoa are found, and Brachiopoda are plentiful, though no longer the predominating forms of life they were in previous ages.

Moreover, the lower forms of life were no longer limited to water-breathing species, or, as in the former age, to a very few insects. The latter are now comparatively abundant. Beetles, cockroaches, grasshoppers, crickets, white ants, may-flies, and other forms appear, while scorpions nearly akin to living forms, though larger, and millepedes, are among the other forms of articulate animals disinterred from the Carboniferous rocks of Great Britain, Nova Scotia, Illinois, Bohemia, and other countries. In Nova Scotia several species of millepedes have been extracted from the

* In his admirable monograph of the genus (*Transactions of the Edinburgh Geological Society,* 1887, pp. 371–397), James Thomson, who has devoted a lifetime to the investigation of Palæozoic corals, describes no less than twenty species, most of which are found in the Lower Carboniferous rocks of the west of Scotland.

interior of erect fossil trees, to which the creatures seem, like their modern relatives, to have resorted for food. As the climate of the Carboniferous period would be especially favourable to the existence of these creatures, the chances are that many more forms than have as yet been discovered will be brought to light by future explorers. But after the close of the Carboniferous Epoch they seem to have declined, none being known in the rocks between that period and the beginning of the Jurassic, while the Centipedes—a higher type of the same family—did not appear until much more recent times. The insects proper of the Carboniferous age belonged to some three orders. Many of them were cockroaches (the "black-beetles" of our kitchens); more than fifty species have in all been discovered. *Lithomantis*—a member of the same group as that to which the "praying mantis" belongs—was a magnificent insect, not unlike some of our modern tropical species, and the *Protophasma* was a near relative of the modern "walking-sticks." Among the many flies there was one (*Haplophlebium barnesii*) from the coal field of Cape Breton which must have had a wing-expanse of seven inches, while another species (*Archæoptilus*) had a wing-spread of fourteen inches, and a species of *Dictyoneura* had wings twelve inches long. The Coal Measures of Saarbrück have yielded several insects allied to the white ants; and, if the conclusion derived from certain larva-like borings on leaves are to be trusted, moths also occurred during the Carboniferous period. One spider is known for certain to have occurred. This form (*Protolycosa*) is from Silesia, and is believed to have belonged to the group of hunting or trap-door species (*Lycosa*). Scorpions in great number and excellent preservation have been found in the Carboniferous rocks both of Europe and of America, some of the richest finds being in Scotland. Several of the insects seem to have been so vividly coloured that they still retain something of their ancient hues. It may be added that some of the Carboniferous insects—and of true insects, apart from arachnida and millepedes, there are nearly 120 species known — combined in themselves types of structure not now united in any individual.* We have thus good ground for picturing the dark, dense, moist woods of the Carboniferous period as by no means silent. On the contrary, the very insect life must have made them resound with that hum which is so characteristic of the modern tropical forest. White ants preyed on the timber, and converted every fallen trunk into dust; millepedes aided in the same work; may-flies and dragon-flies flitted over the stagnant pools and rivers; crickets and locusts and grasshoppers kept up that eternal chant so familiar to every one who has lived in a region haunted by them; while the croak of the huge frog-like batrachians would add variety to the sounds which gave an earnest of the coming times to the forests which we now burn in the shape of coal. Parasitic insects have not yet been detected, and, as there were no mammals or birds at that period, are not likely ever to be discovered, while bees, wasps, butterflies, and moths (for the case mentioned is at best very problematical) could, as Sir William Dawson takes occasion to point out in the memoirs from which some of these particulars have been gleaned, scarcely have flourished in forests from which flowering plants were almost entirely absent.

But insects were not the only lowly land breathers of the Carboniferous jungles. Land snails have been suspected in rocks of Devonian age,† but in the Carboniferous rocks there is no doubt as to their existence. One of them, a *Pupa*, is, though different, similar to some existing West India species, and a *Zonites* from the Coal Measures of Nova Scotia, is in like manner akin to a species of the same genus now living in the Antilles. One of the Pupas also, a Nova Scotian form, seems to have been very abundant, for Dawson found it not only in shales, but in the stumps

* Woodward, *Quarterly Journal of the Geological Society*, 1872, p. 60; Scudder, *Memoirs of the Boston Society of Natural History*, 1883, p. 213; etc.

† The *Strephites erianus* of Dawson, obtained from the hard slaty ridges near St. John, New Brunswick, is allied to the West Indian genus *Strephia*.

of erect trees in beds separated from each other by about 2,000 feet of strata.

The fishes of the Carboniferous age were abundant in species, though, possibly, the individuals of any one form were not so plentiful as during Devonian times. Most of the species were different from those living in that age, though ganoids still predominated, the genera *Palæoniscus*, *Rhizodus*, *Megalichthys*, and *Ctenodus*, being among the most frequent and peculiar. They consisted of both fresh water and marine forms. Indeed, some of them seem, like our salmon and other migratory fishes of the same character, to have been equally at home in salt and fresh water. Many of the Mollusca would appear to have shared this peculiarity. The fish remains found, both in the shales associated with the coal and ironstone seams, and also in some limestones like those of Burdiehouse, near Edinburgh, consist of plates, teeth, defensive spines, and bones, forming more or less complete skeletons. From these fragments we have been able to reconstruct the form and infer the habits of many of the species. *Palæoniscus*, for example, was a tiny species, scarcely bigger than a minnow, while *Rhizodus* was furnished with savage-looking tusks, combined with the usual fish-like characteristics —some of which hint at a relationship to the reptiles which, however, do not appear until a later age. The broad crushing teeth, and the strong, often curiously-sculptured defensive spines, with which some of the species were furnished, suggest waters swarming, like those of the previous Period, with fierce fishes preying on the weaker ones, or themselves the prey of others still stronger, or of the frog-like batrachians, who shared the swampy lagoons with them. Still the Devonian fishes were vastly the superior of those which succeeded them. The Carboniferous fishes are, no doubt, numerous in species (there are upwards of 360 described from the British rocks alone), but, compared with their predecessors, they are fewer in individuals, and smaller in size, while their haunts seem for the most part to have been estuaries and fresh waters. In brief, as Dr. Newberry has remarked, the fishes of the Carboniferous age are no longer like the Ganoids and Dipnoi of the Devonian system

Fig. 74.—RHIZOCRINUS LOFFOTENSIS (1½ TIMES NAT. SIZE.)

(After Wyville Thomson.)

—the "tyrants of the sea." The armoured forms were, therefore, already on the wane,

London: Cassell & Company, Limited.
Edwd Weller, lith. London.

and this decadence went on until, nowadays, out of 9,000 species of fishes, only nine can be ranked among the Ganoids.* Sharks were not wanting in this Period, as shown by their teeth and species, for the soft bodies and cartilaginous skeletons have long ago disappeared, the flat teeth, like those of the Cestracion or Port Jackson shark, indicating the group to which they belong. There were, however, sharp-toothed species also, but while in the sharks of later periods the central point of the tooth becomes dominant, or is developed to the exclusion of the others, in the Carboniferous species the two side fangs of each tooth are the largest, or are exclusively developed. This, Sir William Dawson suggests, may be connected with the fact that in later times the soft-bodied fishes, upon which they chiefly prey, became more numerous than at the Period of which we treat.

However, the Carboniferous strata yield remains even more interesting than any of the preceding ones. There are the bones of air-breathing quadrupeds, not mammals, not even true reptiles, but large amphibians, animals belonging to the same division as that in which the frog and newt are included.

Fig. 75.—ONE OF THE LABYRINTHODONTS RESTORED.

They were of many forms and of all sizes, and belong to several groups. Of more than forty genera, and nearly 120 species described since the year 1841, when the first was discovered, several were nine or ten feet long, while others did not exceed a few inches. But, though belonging to the same order as the frog, the most highly developed of them did not resemble that animal much. On the contrary, judging from the remains before us, most of them were more like the salamander, with relatively short limbs and long tail, the head and inferior portion of the body being cased in armour composed of oval plates in oblique rows, the under edges of which met and formed a ridge along the animal's belly. The most characteristic portion of the bodies

* Traquair: "Monograph of the Ganoid Fishes of the British Carboniferous Formation—Palæoniscidæ" (*Palæontographical Society*, 1877); Miall: "Sirenoid and Crossopterygian Ganoids" (*Palæontographical Society*, 1878); Newberry: "Carboniferous and Devonian Fishes" (*Palæontology of Ohio*, 1873 and 1875); Davis: "Fossil Fishes of the Carboniferous Limestones of Great Britain" (*Scientific Trans. of the Royal Dublin Soc.*, 1883); Günther: Introduction to the Study of Fishes" (1880); etc.

of these animals was, however, their teeth. When cut across, the wall exhibits so many plaitings and foldings as to give rise to a labyrinthine pattern. Hence the name *Labyrinthodon* has been given to a genus of animals in question, and Labyrinthodonts (or *Stegocephala*) to the family which they form. The skull was in shape not unlike that of the crocodile, and—as the bones of fishes and the remains of crustaceans, etc., in their fossilised droppings indicated—they seem to have haunted the fœtid lagoons, much in the same way as alligators and crocodiles do at present, for the purpose of preying on the smaller animals. Many of them belong to this Period; but several are of a still later age, and are now known to have formed the foot markings, which were credited to an animal provisionally termed the *Cheirotherium*, or "hand wild beast" (Fig. 31). In the Carboniferous rocks also there are well-marked footprints which were, no doubt, made by some gigantic frog- or newt-like animal (Figs. 68, 75, 76).

The genus *Archegosaurus*, first disinterred

Fig. 76.—LABYRINTHODON PACHYGNATHUS AND FOOTPRINTS.

from the Saarbrück coal-field, was, perhaps, the most fish-like of all these amphibians, for its long head, short neck, supports for gills, long flat tail, and feeble limbs, hint at a resemblance to the armoured ganoids with which it swam the Carboniferous waters, though the four perfectly-formed limbs, with proper toes, and the nostrils—which infer lungs and the other characteristics of its Order—pronounce it at once to have been a true amphibian, nearly, if not quite, a reptile. *Ptyonius* was an extremely snake-like brute, and, though in all respects amphibian, the probabilities are that it had the habits of water-serpents. Most of the species are comparatively small, two feet being about their limit in length, though indications are not wanting of others much more gigantic having existed. Finally, not to dwell longer on the various amphibians of the Carboniferous rocks—from the fish-like *Archegosaurus* to the crocodile, or, as some palæontologists will still have it, the batrachian or frog-like (Figs. 75, 76) *Labyrinthodon*—we may say a few words on the *Microsauria*, creatures which, though smaller than many of the preceding species, were perhaps more highly organised than any of them. In shape and habits they probably resembled the common lizard of the modern world, though the bony and scaly armour in which part of their bodies was encased removed them from too near a kinship with these animals. It is more than possible that in time it will be discovered that true reptiles, or at least animals of a higher grade than amphibians, existed during this Age. Meanwhile, it is not safe to accept any conclusions to that effect.

All of the preceding animals were amphibians, that is to say, like the frog, they went through a tadpole stage before assuming their perfect form. It is, indeed, one of the most remarkable of the many amazing facts which we meet with in rehearsing the story of the Earth, that with the advent of the Carboniferous Period the strange assemblage of animals made their appearance. They might have come gradually; if the evolutionists are not in error, they must have developed by the process which Darwin has made familiar to every one—from pre-existing ancestors. These ancestors may yet be discovered; meanwhile we are face to face with the fact that, while in the preceding age—the age which seems to have glided so quickly into this—there was barely more than a hint at anything higher than fishes, the swamps and waters of the

Carboniferous world swarmed with amphibians, compared with the abundance of which the Egyptian plague of frogs must have been only a pleasant diversion from the monotony of life in the Nilotic Delta. Yet the least developed of these animals are so far removed from the most highly-developed fish of the Devonian and Old Red Sandstone that, admitting every claim put forward by the most pronounced exponent of Darwinism, it is difficult for the finite mind of man to conceive the immense lapse of time necessary for them to have advanced from the only ancestors which can for the present be assigned to them, until they attained the shape in which they are known to us. The lacunæ may be filled in: we are sanguine that they will. Some formation in a land still unexplored by the geologist, or covered by the sea, may reveal the missing links, or—improbable though this assumption is—establish the proofs of an enormous gap in time having elapsed between the close of the one and the beginning of the other period. At present, however, we must take the facts as they are.

Amid so strange an assemblage of animals as those by which we are now surrounded, it is like touching land again to find that the habits of those old-world amphibians, and the lowlier forms on which they fed or among which they lived, were very much what those of their remote descendants are. In Carboniferous times, as in ours, the millepedes and land snails took refuge or sought food in hollow trees, and the amphibians in pursuit of them fell into these cavities, and there remained until the hammer of the geologist released them. This is no dream. In the South Joggins coal-field of Nova Scotia various Sigillariæ—gigantic club mosses (though some botanists will insist that they were more nearly akin to cycads)—very characteristic of the Period, stood at more than sixty levels. In one of these Sir William Dawson (to whom we are indebted for so much of our knowledge of Canadian geology, and especially of the Carboniferous Age) found a curious assemblage of contemporary animals. The interior had rotted away unnumbered ages ago, and the ground around the opening thus made had become clothed with ferns and reed-like Calamites, partly masking and concealing it, just as would happen—*mutatis mutandis*—at the present day. "And now millepedes and land snails made the buried trunk a home or fell into it in their wanderings; and small reptiles [amphibians] sporting around in pursuit of prey, or themselves pursued, stumbled into the open pitfall and were unable to extricate themselves; though I have found in some of the layers in these trees trails which showed that these imprisoned reptiles had wearily wandered round and round, in the vain search for means of exit, till they died of exhaustion and famine. The bones of these dead reptiles, shells of land snails, and crusts of millepedes, accumulated in these natural coffins and became mixed with vegetable *débris* falling into them, and with thin layers of mud washed in by the rains; and this process continued so long that a layer of six inches to a foot in thickness full of bones was sometimes produced. At length a new change supervened, and the area was again inundated and drifted over with sand, and the hollow trunk was filled to the top and buried under many feet of sediment, never to be reopened till after the whole had hardened into sandstone and elevated to form part of the modern coast, when the old tree and its forest companions, which had shared the same fate with it, are made to yield up their treasures to the geologist."* In the trunk described were found two species of *Dendrerpeton*, an amphibian allied in structure to two species now inhabiting the North American rivers, and a third small lizard-like species seven inches long. In a second tree Sir William Dawson found nine skeletons belonging to four species, in addition to many land shells and centipedes (*Xylobius sigillariæ*).

* Dawson: "The Chain of Life in Geological Time," p. 161; "Acadian Geology," p. 385; Miall: "Report on the Labyrinthodons of the Coal Measures" (*Reports of British Association*, 1873, 1874); Cope: Synopsis of Extinct Batrachia from the Coal Measures" (*Palæontology of Ohio*, Vol. II., 1875).

CHAPTER VII.

Palæozoic Rocks: Coal Plants and Coal: Permian System.

The Carboniferous Period essentially one of Plants so far as its Later Stages are concerned—The Coal Beds a visible proof of this fact—Even the Shales full of Plants and Vegetable Matter—Notice of some of the more Remarkable of these Plants—The Ferns—The Calamites—The Lepidodendra—The Sigillariæ—True Conifers, like Pinites, Dadoxylon, etc.—Various Names applied to Fragmentary Plants now known to be portions of some of the above—Antholites, Trigonocarpum, and others—Flowering Plants probably not absent, though not known for certain to have occurred—Asterophyllites and Pothocites—Their true Affinities—Climate of the Coal Measures—Physical Geography of the Period—Volcanoes, etc.—Changes during the Deposition of the different Beds—Scenic and Economic Aspects of the System—Coal: its Formation—Exhaustion of our Coal Mines—The Permian System—Its Range—Its Classification—Its Main Features—The Life of the Period—The Physical Geography of the Age—The Economic and Scenic Aspects of the System—Permian Salt and Coal—etc.

The Carboniferous Period was, however, not only an age of Amphibians like those described. It was emphatically the Age of Plants. To use the eloquent language of Hugh Miller in addressing a London audience many years ago—though the words are quite as applicable now as then—"in no other age did the world ever witness such a flora; the youth of the earth was peculiarly a green and umbrageous youth, a youth of dusk and tangled forests, of huge pines and stately araucarians, of the reed-like calamite, the tall tree fern, the sculptured sigillaria, and the hirsute lepidodendron. Wherever dry land, or shallow lake, or running stream appeared, from where Melville Island now spreads out its ice wastes, under the star of the Pole, to where the arid plains of Australia lie solitary beneath the bright cross of the South, a rank and luxuriant herbage cumbered every foot-breadth of the dank and steaming soil; and even to distant planets our earth must have shone through the enveloping cloud with a green and delicate ray. Of this extraordinary age of plants, we have our cheerful remembrancers and witnesses in the flames that roar in our chimneys when we pile up the winter fire, in the brilliant gas that now casts its light on this great assemblage, and that brightens up the streets and lanes of this vast city; in the glowing furnaces that smelt our metals, and give moving power to our ponderous engines—in the long dusky trains that, with shriek and snort, speed athwart our landscapes—and in the great cloud-enveloped vessels that darken the lower reaches of your noble river and rush in foam over ocean and sea."

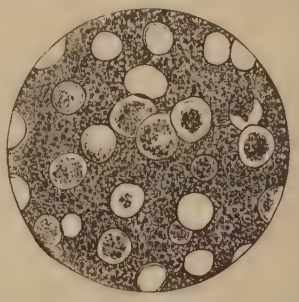


Fig. 77.—THIN SLICE OF SHALE FROM KETTLE POINT, LAKE HURON, GREATLY MAGNIFIED: SHOWING THE LITTLE GLOBULAR SPORE-CASES SCATTERED THROUGH IT. *(After Nicholson.)*

Carboniferous Fossils.—*Plants.*—The testimony to the truth of these statements is found in the coal itself, and in the rocks with which it is associated. If a thin section of an ordinary piece of coal is put under the microscope its vegetable structure may frequently be at once detected. What is more, many specimens exhibit the spore-cases, or bag-like representatives of what serves for seeds, in the low orders of plants which have mainly

contributed to the formation of this fuel. In some of the black shales which form the "roof" of the coal seams, such as those from Kettle Point on the shores of Lake Huron, which burn readily, these spore-cases are equally abundant. Even to the naked eye they are quite plain in the form of little brown specks (Fig. 77). They tell of muddy shores, along which grew dense jungles of tree ferns, gigantic club mosses, and huge horse-tails, which shed their dust-like "seed" into the soft material of the future shales, under the shadow of their branches, until it got impregnated with the resinous material — a material, it may be added, which is so inflammable that the similar dust of modern club mosses is used in theatres to produce artificial lightning. We see, indeed, much the same process going on at the present day. The margins of lakes bordered by pine and fir forests are often covered with a yellow dust which, on examination, is found to be the pollen of various coniferous trees, and which, when wafted by the wind to a distance, constitutes a nine days' wonder in the shape of one of those "sulphur showers," notices of which at times appear in the newspapers. On the shores of a lake* in Vancouver Island, in a deep hollow shut in by forests of *Abies douglasii*, the writer has seen a layer several inches thick almost entirely composed of dead shells of the ordinary water snail (*Limnæa stagnalis*), and of the old seeds and fresh pollen of the neighbouring conifers. Not only are some coals (the "white coal" of Australia, for example) almost composed of the "spores" or seed-like bodies of club mosses and their allies—which played much the same part in the forests of the Carboniferous Age which coniferæ do in those of western and eastern North America—but in the lignites or brown coals (Vol. I., p. 59) of comparatively recent formation which are worked for fuel in various parts of the world, in addition to the microscopic vegetable structure, the original fibres of the woody material, stems, twigs, and leaves, may frequently be seen at a glance in any lump dug out of the seam.

These facts, and many equally potent,

Fig. 78.—CALAMITE RESTORED. (*From 30 to 40 feet high.*)

are in ample evidence, not only regarding the vegetable origin of coal, but as to the abundance of plants which existed during the Age when these deposits were formed. Yet, of the many species found in the shales and sandstones already described—and remains of every family of plants scattered through them have been met with in the coal itself — the vast number are of the

* Horne's Lake, between Qualicom and Alberni; Brown, "Das innere der Vancouver Insel" (Petermann's *Geographische Mittheilungen*, 1870).

Acrogenous type (Fig. 37), that is to say, they belonged to the ferns, club mosses, and horse-tails, or were flowering plants so low in the scale as coniferæ. At present, something like 1,700 species of plants are known from the Carboniferous rocks. But of these nearly

Fig. 79.—ALETHOPTERIS LONCHITICA: A CARBONIFEROUS FERN.

one half are ferns, while of the remainder the Lycopodiaceæ, or club-moss Order, and the Conifers, constitute the largest portion.* Hence the Carboniferous Period has been termed the "Age of Acrogens."

Ferns abound in every seam of shale, and specimens may be picked up in the refuse around any newly-opened coal-pit or boring. Most of them are without the spore-cases on the back of the fronds. Hence, as the shape of the foliage of all ferns is notoriously variable, it is sometimes difficult to say for certain that all the species described are distinct one from the other. However, the specimens found are so well-preserved, that the forked venation (so distinctive of the Order) and the general outline of the plants can be studied almost as well as in the dried specimens of the botanist's herbarium. Moreover, as the fronds are generally detached from the stems on which they grow, it is only now and then that we can say positively that the stem and foliage are not two species, or even two separate genera. This, however, is a difficulty which often presents itself to the palæontologist. Many of these ferns, though all of extinct species, are so like some living forms, that it is sometimes puzzling to say whether a form like *Pecopteris* is not referable to the same genus as the more familiar types seen

Fig. 80.—SPHENOPTERIS ARTEMISIÆFOLIA: A CARBONIFEROUS FERN.

in modern woods. On the other hand, the bulk of the Carboniferous plants are so weird that it is still an open question to which of the great vegetable groups they should be assigned. Most of the ferns were probably arborescent, like the tree ferns of New Zealand, Mauritius, Brazil, and other modern countries; and in *Caulopteris*, the scars marking the places where the fallen fronds had been attached impart a certainty to this belief. *Sphenopteris* (Figs. 26, 80), *Palæopteris*, *Alethopteris* (Fig. 79), *Neuropteris*, *Lonchopteris*

* The exact percentages are given by Lester Ward in the *Report of the United States Geological Survey* for 1883–84, pp. 440, 441; but as new forms are constantly being discovered, it is unnecessary to reproduce these statements.

(Fig. 81), etc., are some of the most common genera found among the British fossil ferns.

The *Calamites*, which also figure extensively among the coal plants, were evidently gigantic representatives of the lowly equiseta or horsetails of our times, the chief difference lying in their enormous size, the want of sheaths at their joints, and in special points connected with their fructification and the structure of

Fig. 81.—LONCHOPTERIS BRICII: A CARBONIFEROUS FERN.

their stems* (Fig. 78). Their cone-like fructification was, most probably, the plant described under the name of *Volkmannia*, and some botanists have little hesitation in affirming that *Sphenophyllum* (Fig. 88)—already, like *Asterophyllites*, seen in the Silurian—and *Annularia* are not more than different forms of the foliage of Calamites. Even *Calamodendron*, sometimes regarded as the cast of the space occupied by the pith of some unknown tree, is beginning to be regarded as another type of the somewhat variously organised Calamites.

The Lepidodendra, of which many species have been described † (Fig. 82), are quite as clearly allies of the club mosses—the witches'- or foxes'-tethers of our moorlands (*Lycopodiaceæ*). However, while the latter are humble plants which creep along the ground,‡ the various species of Lepidodendron were large trees, which branched towards the top, the leaves being sometimes attached to the thick trunks, though most frequently they are detached, the lozenge-shaped markings on the bark showing the cicatrices where they had dropped off. The fossil cones named *Lepidostrobus* are now known to have been the strobili or fruits of the Lepidodendron, and the plants described as *Knorria* (*aviculare*, etc.) were most probably the internal cylinders or coats of the interior of decayed specimens of the same ancient club moss. *Halonia*, *Ulodendron*, and *Cyclocladia*, were, however, genera of true Lepidodendra.

Sigillaria was an even more common genus in the Carboniferous jungles, for erect stems of it (Fig. 27), with its roots § (*Stigmaria*) in the underclay (p. 93), are found in almost every coal-basin or seam. Like the Lepidodendra, they were tall trees, with trunks fluted longitudinally, the seal-like markings (from which the genus takes its name ‖) being the scars or pits showing the points at which the leaves were attached. The interior of the trunk seems to have decayed more rapidly than the bark. At all events, when found in the rocks the Sigillariæ are usually flattened, the two opposite sides of the bark being converted into bright shining coal, lying one above the other in horizontal layers, as if the rotten or hollow tree had been squeezed down after it fell, and got entombed in the mud. The leaves (originally described as *Cyperites* before their relationship to the Sigillaria was known) were long and narrow, and the tree itself sometimes attained a height of seventy feet. From the fruit it appears that Sigillaria was an acrogen belonging to the club moss Order, and, therefore, allied to the Lepidodendron, though Sir William Dawson inclines to the belief that

* Williamson, *Philosophical Transactions*, 1871, p. 477.

† Williamson, *Philosophical Transactions*, 1871, p. 197; 1872, p. 283; etc. Indeed, all of Professor Williamson's series of memoirs on the structure of Carboniferous plants are well worth studying, even if exception may be taken to some of his conclusions.

‡ *Lycopodium densum* of New Zealand rises to the height of about three feet.

§ M. Renault (*Considérations sur les Rapports des Lépidodendrons, des Sigillaires et des Stigmaria*, 1883) considers Stigmaria not properly a root, but an underground stem or rhizome from which rootlets proceeded.

‖ Latin, *Sigillum*, a seal.

some, at least, of the fossils described under that name are, like *Clathraria* and *Lepidophloios*, more akin to the Cycads. Possibly also the genus *Nœggerathia*, usually described as ferns, may belong to the latter Order.

Fig. 82.—LEPIDODENDRON STERNBERGII (RESTORED) (40 *feet high*).

True coniferæ were, however, not absent from the Carboniferous forests in the shape of the genera *Pinites*, *Dadoxylon*, *Araucarioxylon*, *Cordaites*, etc., several of which began to appear in the Devonian Period. All of them, however, seem to have differed considerably from the modern species of the Order in having very large piths, which pith was at one time believed to be a peculiar genus of plants called *Stenbergia*, or, rather, it was the cast of the cavity formed by the absorption of the original central substance in the genus Dadoxylon. In other respects they were more akin to the Araucarias of the South, the "monkey puzzle," or Chili pines, ornamental trees now common in so many gardens. Others, like Cordaites, which had already appeared in the Devonian (a System out of which specimens of Dadoxylon have been disinterred in New Brunswick), was, perhaps, more nearly akin to the yews, though with broad leaves like the modern Dammaras. The seeds described as *Trigonocarpum* were probably produced by various genera of coniferæ allied to the yews, numerous forms of these occurring in the sandstones, ironstones, shales, and in the coal itself. Indeed, there are localities in which bushels of these fossil seeds can be obtained in almost any bed connected with the coal-seams, except the limestone and the underclay. Such seeds are found in many coniferæ, which, like the yew tribe, and the genus *Salisburia* especially, produce fleshy solitary fruits, and not cones; and that they were borne by many different species is proved by the sixty or seventy different forms of *Trigonocarpum* which have been figured.

Antholites was at one time universally regarded as a flowering plant in the strict sense of the term, but of late years it has been considered as the foliage of Cordaites, the spikes of which were described as *Carpolithes*, and its fruit as *Cardiocarpum*;* or, to put the matter in a more correct way, Cardiocarpum is, according to this view, the fruit of Antholites or of Cordaites, whichever generic name may be selected for preservation.

True flowering plants were probably not altogether absent from the Carboniferous

* This is proved by *Cardiocarpum* being found attached to Antholithes, though it is not justifiable to assign the latter plant to the Calamites, as some investigators seem inclined to do. See Williamson, *Philosophical Transactions*, 1873, p. 41; Charles Peach, in *Transactions of the Edinburgh Botanical Society*, Vol. XI., p. 108; Dawson: "Geological History of Plants" (1888), pp. 82, 132, 153.

forests. At the same time, the data for inferring their presence are meagre in the extreme, and, little by little, are every day getting less and less, so far as actual fossil evidence is concerned. Antholithes was, for instance, once looked upon as an ancient broomrape which grew parasitically in the roots of trees, like its modern representatives. But though this belief is not tossed altogether into the limbo of superseded fancies, it will be seen that botanists are now searching for its affinities in quite another direction.

Fig. 83.—SWAMP WITH BANYAN-TREES IN THE ISLAND OF UALAN IN THE CAROLINE GROUP. (*From Kittlitz.*)

Again, the curious *Pothocites grantoni*, which Dr. Robert Patterson in 1840 found in the Carboniferous shales near Granton on the Firth of Forth, was, until lately, almost universally regarded as an ancient arum, like the "cuckoo-pint" of Europe, or the "skunk-cabbage" of America. More accurate observations have, however, thrown doubts upon this identification, in favour of *Pothocites* being the fruit of *Bornia*,* a genus of Calamiteæ, which began to appear in the Devonian, and continued through the Carboniferous System. In brief, though many gigantic representatives of types now degraded to a few and, from the point of size, unimportant forms, cumbered the steaming jungles of the Carboniferous Period, almost none, or none which have descended to us, of the more familiar broad-leaved trees of the tropical forest had come into existence. Flowering shrubs and parasites were absent. Fungi existed, but the majority of the trees were great ferns, club mosses, and other cryptogamic plants of these Orders.

Physical Characteristics of the Carboniferous Period.—At the same time, it is raising a needless issue to infer, as Dr. Sterry Hunt has done, that these tangled woods were enveloped in an atmosphere more densely charged with carbonic acid gas than that of later times. This excess of carbon might possibly benefit the plants, but we have no room for believing that the amphibians of the Period, or the other true air-breathers which swarmed under the trees, were, any more than their modern relatives, capable of subsisting in such a poisonous atmosphere. In reality, there is no reason to doubt that the climate of that Age was in any degree abnormal. That it was moist, may be inferred from the abundance of ferns which flourished, though this also is a conclusion which admits of some doubt. At all events, it was not dry, and, perhaps, as Sir Joseph Hooker has suggested, the Carboniferous World was, so far as heat and cold were concerned, not widely different from the North Island of New Zealand, a country famous for forests of tree ferns and club mosses of robust growth. The climate of the Coal-forming Age must, however, have been uniform over a very wide region, which is at present meteorologically very varied. This is indicated by the monotony of the vegetation. From the Arctic Regions—that is, where the Arctic Regions of our era are—to the Zone, which now lies under the Equatorial sun, the rocks yield a singular sameness of genera and species, and it is by no means uncommon to find the same form ranging all round the world wherever the Carboniferous rocks have been laid down. Even then, it is certain that not a tithe of the plants have been preserved. The vegetation which we find entombed in the rocks was essentially that of the lowlands, of the swamps, seashores, and the borders of muddy lakes or lagoons, such as those seen in many parts of the world at the present day (Fig. 83). On the high lands a very different flora, no doubt, flourished. Hence, though conifers are few and club mosses many, it does not necessarily follow that the former were quite so scarce as the paucity of their remains might seem to indicate. They grow, as the nature of such trees is, in breezier situations than those loved by the species now so frequent in the Coal Measures, an occasional trunk or cone washed down by tropical rains, or tossed to the lower levels by the mountain torrents, being the portions most likely to be fossilised in the mud of which the shales are composed. Their stems have, however, been met with in the volcanic tuffs of the Carboniferous Age, suggesting the extreme probability of the sides of the old volcanoes having been clothed with their trees, as so many burning mountains are at the present day. Then, when an eruption occurred, the trunks would get buried in the falling ashes.

That the Carboniferous Age was one of volcanoes, we know from other data quite as conclusive. Volcanic rocks are associated with Carboniferous beds in various parts of the world. These sheets, consisting of traps and tuffs—that is, of lavas and volcanic ash—are usually limited to the lower members of the series, though in many cases they are

* Kidston, *Annals and Magazine of Natural History*, 1883, p. 297.

thick enough to form hills of considerable size, in spite of the erosion to which they had been subjected during the ages succeeding the Carboniferous Period. Brent Tor, near Tavistock in Devonshire, is an extinct volcanic cone, and many of the best-known hills in the Scottish lowlands are of this nature. Arthur's Seat (Fig. 86) and Craiglockhart Hill near Edinburgh, the Bass Rock in the Firth of Forth, and North Berwick Law a few miles distant, Saline Hill and Largo Law in Fife, are, for example, all more or less perfect volcanoes of the lower Carboniferous Period, the subterranean eruptions being limited to the age of which the rocks under the Millstone Grit are the tangible memorials. In this Period there must have been endless volcanic vents all over the country, since, in addition to such more or less perfect single and double cones as those described, there are many, like Binn's Hill in Linlithgowshire, which are only the stumps of the old volcanoes, while volcanic "necks," and other evidences of dormant vents, are numerous all over the south and west of Scotland.* Ireland was equally the scene of violent volcanic disturbances during the period when the Carboniferous limestones were being accumulated, and in Derbyshire, the interbedded lava sheets known as "toadstones" are evidence of a similar activity in that part of England. But, though the period during which the Carboniferous world was thus shaken was, in the main, its earlier stages, the outbursts of lava were not limited to the Carboniferous limestones, and the strata at the base of that group. This we learn from the fact of the Staffordshire coal-field being penetrated by outbursts of an identical character with those already described, the Rowley Hills and Barrow Hill being memorials of these intrusive lavas.

The Whin Sill of Northumberland is another remarkable specimen of an intrusive basalt belonging to this era. It varies in thickness from a few feet up to 200, and appears at all elevations, from 1,000 feet down to the sea level, in the course of its rugged precipitous course from near Brough in Westmorland, across the upper parts of Teesdale and Weardale, round the western escarpment of the Pennine Chain, and across the valley of the North Tyne at Gunnerton. Here it divides into two streams, one of which reaches the sea at Howick, from whence it reappears in the Farne Islands, and a variety of other well-known features in Northumbrian scenery, until it terminates in the precipice known as Kyloe Crags.

At the beginning of the Carboniferous Period the basins of the Devonian Age (p. 84) were not entirely submerged under the sea, for we see in some of them a mixture of the Carboniferous species, which had then begun to appear. Lakes or estuarine waters seem also to have held their own in places, as is evinced by the presence of the peculiar fishes and other fossils of the Burdiehouse Limestone, until the submergence continuing, only a few islands appeared above the surface of the Carboniferous sea. The Silurian district in Cumberland was one of these islands, while it would appear that the region extending from North Wales through the Midlands was another; though here and there over the whole area of the space now occupied by the United Kingdom land masses of a greater or less extent peered above the surface of the ocean. Marine conditions must, however, have very generally prevailed, since the majority of the fossils in the beds deposited during this period are of salt-water origin. That there was constant and considerable submergence the great depth of the Carboniferous Limestone testifies. Oscillations of land and sea can be proved by the alternation of marine and terrestrial remains in some of the beds of this Age, and in time the erosion of the rocks above water was so extensive that the bays and shallow estuaries got filled up, and a dense vegetation grew on the surfaces thus formed while

* Arch. Geikie, *Trans. of the Roy. Soc. of Edinburgh*, Vol. XXIX., p. 458; and "The Geology of Edinburgh and its Neighbourhood" (1871); "Memoirs of the Geological Survey of Scotland" (Explanation of Sheets 32 and 22); Fleming: "Lithology of Edinburgh" (1859); Maclaren: "Geology of Fife and the Lothians" (1866); Cunningham: "Geology of The Lothians" (1836); etc., etc.

volcanic activity was constantly in progress. By the time the Millstone Grit was laid down this vulcanicity had waned. The Millstone Grit is, to a large extent, estuarine, and, as fireclay and coal prove, land must have been general during the period of its deposition. With the advent of the age of the Coal Measures the marine conditions seem to have ceased. A vast amount of land had then risen above the waters, since every seam of coal represents a vast amount of terrestrial vegetation, with the underclay as the soil on which it grew. Oscillation must, however, have been going on, since, apart from the sandstones and limestones which alternate with the coal-seams, the shales of the pit roof point to the vegetation having been submerged and overlaid by silt. The coal plants grew, most likely, on the low flats bordering lakes or estuaries or rivers, like the mangrove swamps of the West African rivers, or on the Indian coast (Fig. 84), or the cypress swamps which line either shore of the Lower Mississippi River; and, therefore, even when a more permanent submergence of the soil on which they grew did not happen, must have been subject to constant flooding, so that bituminous shales, like so many in the Coal Measures, containing fish remains, and fresh-water or brackish shells, etc., may have frequently formed. Many of the "gas coals" are made up of this vegetable slime; and the blackband ironstone, which often graduates into gas coal, also contains occasional fossils, plainly intimating the conditions under which it might have been formed. The bands and nodules of clay-ironstone are formed of carbonate of iron mechanically mixed with earthy matter. From experiments made by the late Robert Hunt, it has been found that decomposing vegetable matter prevents the farther oxidation of the protosalts of iron, and converts the peroxide into protoxide by taking a portion of its oxygen to form carbonic acid. This carbonic acid, meeting with protoxide of iron in solution, would unite with it and form a carbonate of iron. Finally, this material, mingling with the fine mud deposited from the overflow of rivers, or from other causes, might form beds or nodules of clay-ironstone when the excess of carbonic acid was removed.

The coal-beds were, however, even in those early times, subject to erosion. It is by no means uncommon to find proofs of many having been swept away or greatly reduced in thickness. Underclay exists without the vegetation which grew on it in the shape of a coal-seam, while these "wants," as the miners term them, are occupied by sandstone and shale; though in the underclay, which is almost universally present, the roots of the Sigillariæ and other plants remain undisturbed.

The coal-beds are of all thicknesses, from a mere film to two hundred feet;* though sometimes, owing to the thinning out of the sandstone or shales between them, two thin beds will, towards their ends, unite to form a single thick one. This condition of affairs prevailed all over Europe, though it would appear that in the eastern portion of the area the seas were shallower than in the west. Professor Green has so succinctly described the changes in progress during the deposition of the Yorkshire Carboniferous beds that his words may be quoted, since, with a few alterations, they apply equally well to any other area of a similar character. At that period Western Europe was to a large extent occupied by a sea comparable to the modern Mediterranean. "This Mediterranean Sea," it is the opinion of this eminent geologist, "had a fringe of shallow water round its margin, and deep depression in its central portion. Round its edges deposits were formed, mainly of mud and sand, though every now and then calcareous animals established themselves in sufficient numbers to give rise to beds of limestone. At a certain

* Forty-five feet, which is the thickness of the so-called "Ten-Yard Seam" in South Staffordshire, is the maximum of any English coal-bed. However, in India, Pennsylvania, and the South of France, the layers are often very much thicker. In most parts of the world shafts have to be sunk in order to pierce the beds of coal, or tunnels run in along the stratification of the deposit. But in Bengal (near Raniganj) a fifty-foot seam has been laid bare over an area of several acres, the coal lying within ten to thirty feet of the surface.

Fig. 84.—MANGROVE THICKET AT GOA ON THE MALABAR COAST, AT EBB-TIDE.

(From a Photograph.)

distance from the shore all the sediment sank down to the bottom, and beyond this limit the water was bright and clear, and the only deposit consisted of accumulations of the hard calcareous parts of marine animals, which are now pure limestone. In the deep hollows the deposits of limestone reached a great thickness; over the ridges which parted the hollows it was not so thick. This will explain how it is that the Carboniferous Limestone shows such great variations in thickness at different spots. The growth of the limestone gradually filled up the deeper parts of the sea, and at last the area became as shallow throughout as it had been originally only at its edges. The mixed deposits of sandstone, shale, and impure limestone, which had at first been confined to the neighbourhood of the shore, now extended themselves over nearly the whole marine tract, and the deposition of the Yoredale rocks began. At the same time a slow sinking of the sea bottom set in, which allowed of these beds being piled one on the top of the other to a considerable thickness. After a time a further important change took place. Either by the outlets becoming blocked up, or by the upheaval of a portion of the bottom, the land-locked area, in which the lower marine portion of the Carboniferous rocks was deposited, became cut off from communications with the ocean on the west, and converted into a fresh-water lake or a large estuary, which received the waters of rivers flowing from the north, east, and south. In this fresh-water or brackish area the Millstone Grit and Coal Measures were deposited. The water was never very deep, but the subsidence which had begun in Yoredale times went on during the deposition of the beds next above, and they too, in consequence, reach a great thickness. When the water was at its shallowest, currents piled up banks of sand, or drifted coarse materials over the bottom and shot them down into hollows, and thus formed lenticular beds of sandstone, or washed down and spread out pre-existing sand-banks, and gave rise to more regular sandstone beds. When the depth was greater, only fine mud was brought into the water, which settled down into more regularly-bedded and uniform deposits of shale. The subsidence, which allowed of the growth of the mechanically-formed deposits, did not go on without interruption. Every now and then a pause occurred, and, whenever this happened, the water became filled up, and there was a tendency to the formation of low, swampy flats. Perhaps occasionally small upheavals helped in the production of this result"* (Fig. 85).

The climate of the Carboniferous Age must, on the whole, have been an equably warm one. Yet, even in a sea of a temperature so uniform that the same species of animals could flourish over a vaster region than any modern species can, ice occasionally floated. At all events, erratic blocks have been detected among the Carboniferous beds of Southern Europe and America. As there seems to have been little lofty land during the Age of the world with which we are at present concerned, the agent employed in bringing these travelled stones from a distance could scarcely have been glaciers or even icebergs. More likely, as Sir William Dawson suggests, it was floating ice, though where this ice came from is a question which may reasonably admit of much discussion and some degree of doubt.

Scenic and Economic Aspects of the Carboniferous System.—Man has so altered the scenic features of almost every region where Carboniferous beds are found, that it is difficult for us to picture them apart from the tall chimneys belching out smoke, the furnaces smelting the ironstone or turning the coal into coke, the unsightly stacks of coal and coal-refuse at the pit-mouths, the endless cranes and waggons and railways engaged in winning and transporting the coal and ores, the kilns employed in converting the limestone into lime, or the retorts for distilling the oil shales. Everywhere a Carboniferous region is grim, smoky, and, except to those who can look beyond the crudities before him, unpicturesquely prosaic. It is the land of

* Green and Russell: "The Yorkshire Coal Field" (*Memoirs of the Geological Survey*), p. 24.

coal mines and smelting works, of blasted vegetation and a dusky atmosphere, while the traveller who runs through it by night is ever and again reminded of the vast industries to which the imprisoned sunlight of the Carboniferous Age has given rise, by the glare from the furnaces of the Black Country illuminating the darkness, or by the clang of hammers that ring out in the silence of mid-

raw material of the mortar with which is laid the sandstone that beautifies Edinburgh and relieves the ugliness of Newcastle; while the marbles of Derbyshire and Kilkenny, with their encrinites and corals, supply a decorative material for chimney-pieces and other household purposes. The "grindstone post" of Northumberland is the sandstone which furnishes the ubiquitous "Newcastle

Fig. 85.—COAL-MINE AT TREUIL, ST. ETIENNE, FRANCE, SHOWING THE TRUNKS OF FOSSIL TREES TRAVERSING THE OVERLYING STRATA OF SANDSTONE. (*After Ad. Brongniart.*)

night. Here are great towns, enveloped in murky clouds discharged from the forests of chimneys which break the sky line in every direction; mills, in which thousands of spindles are weaving the cloth in which half the world is clad; machine shops, in which are forged the engines by which wealth is earned, or the lethal weapons by which it is wasted. There are the quarries, out of which are hewn the stone of which cities are built; here the kilns in which is burnt the limestone, which is the

grindstones." The black-band and clay-carbonate ironstones form an inconsiderable portion of the ores reduced in the British Isles, while the fire-clay, out of which bricks, tiles, and the like are made, is dug from nearly every coal-field, its value as a material for the manufacture of bricks subjected to great heat being its power of resisting slagging or vitrifying.

There is, indeed, little waste in a coal-field. The shales of bituminous clay yield naphtha,

paraffin, paraffin oil, and other illuminants on distillation, their richness being due to the amount of vegetable matter, identical in character with that of coal, which they contain. Indeed, not a few shales are almost as combustible as the poorer varieties of coal (p. 101), their main difference being a physical rather than a chemical one. In other words, a shale is fissile; it splits into layers — which it is almost unnecessary to say is not a characteristic of even the earthiest of coals, the varieties which leave behind an inordinate amount of ash, this ash being the incombustible portion of the lumps burnt in the fire. Other shales are rich in alum, and in various localities in Germany and Scotland—near Glasgow, for example—furnish the material for a busy industry. Others, again, furnish copperas or green sulphate of iron. Ochre—that is hydrated oxide of iron—is found in several places in the Carboniferous region, while permeating the Carboniferous limestone are rich veins of antimony, zinc, and lead, much of the latter containing a desirable percentage of silver.

Yet a Carboniferous country is not generally attractive, except for what lies beneath the soil. Its scenery is usually tame, unless where the basaltic cones, like the hills mentioned, break the monotony of the country, standing, as they generally do, isolated, or where the "mountain" limestone rises into elevations sufficiently high to justify its familiar name. Sometimes where a river has cut a deep glen through the Carboniferous beds, the scenery, as in the case of the tributaries of the Tyne, is picturesque. As a rule, however, a Carboniferous district, even when not marred by the hand of man, is not to be compared with the wilder-featured regions covered by the older formations. Nor is the soil generally rich. The exceptions to this rule are when, as in the Lothians of Scotland, the crumbled-down volcanic rocks and sandstones have imparted richness to the colder shales and clays. Even the limestone country is not much in favour with the former, especially when it is elevated, so that from Northumberland to Derbyshire there are wide tracts unfitted, except in the dales, for ordinary agricultural operations. The Derbyshire limestone tract is, for the most part, high and grassy pasture lands, intersected by cultivated valleys. The Millstone Grit ridges to the east and west are elevated heaths, while Kinder Scout to the north is a moss-covered plateau 2,000 feet above the sea, and still farther north between the Yorkshire and Lancashire coalfields, "all the way to the borders of Scotland, east of the fertile Vale of Eden, the country may be described as a great high plateau sloping gently eastward, through which the rivers of Yorkshire and Northumberland have scooped unnumbered valleys."

Sir Andrew Ramsay, whose words have just been quoted, characterises the uplands as generally heathy, with occasional tracts of peat and small lakes. But, when formed partly of limestone, grassy mountain pastures are apt to prevail, through which "blind roads" run northward to Scotland, as so graphically described in "Guy Mannering." Tillage is less frequent, but here and there the deeper valleys are cultivated, dotted with villages, hamlets, the seats of squires, farms, and the small "lairdships," as they would be called over the Border, of those fast-vanishing yeomen or "franklins" known in Cumberland and Westmorland as "'statesmen."* "Of this kind of land the Yorkshire dales may be taken as a type. Nothing is more beautiful than these dales, so little known to the ordinary tourist. The occasional alluvial flats of the Calder, the Aire, Wharfedale, Niddlesdale, Wensleydale, Swaledale, Teesdale, Weardale, the Derwent, and the valleys of the North and South Tyne, all alike tell their tale to the eye of the geologist, the artist, and the farmer. The accidental park-like arrangement of the trees, the soft grassy slopes leading the eye on to the upland terraces of limestone or sandstone, which, when we look up the valleys, are lost in a long perspective, the uppermost terrace of all sometimes standing out against the sky, like the relic of a great

* An abbreviation for "estatesmen." In 1794, two-thirds of the county of Cumberland were held by these sturdy yeomen.

Fig. 86.—ARTHUR'S SEAT, EDINBURGH—VOLCANIC HILL OF LOWER CARBONIFEROUS PERIOD.

Cyclopean city of unknown date, as in the time-weathered grits of Brimham Rocks (Vol. I., p. 351)—these, together, present a series of scenes quite unique in the scenery of England." *

Coal, however, is what renders the Carboniferous system the most important of all the geological formations of Great Britain. Without it the other products of these rocks would be of little value, while the metals permeating others could only be melted at a cost so high that they would be unmarketable did not the fuel and the ore lie side by side. The nature and principal varieties of this substance have already been sufficiently described (Vol. I., pp. 58-60). That it is vegetable matter transformed by the partial elimination of oxygen and hydrogen by slow oxidation under water is now universally admitted. That process can take place under any circumstances which would keep the vegetable matter from contact with the atmospheric air. Otherwise the wood, instead of being converted into coal, would decay into vegetable mould. The quality of coal varies with its age and the nature of the plants which have entered into its composition. If the coal is of comparatively late date it is lignite, while in the oldest coal—what, indeed, is in England ordinarily called by that name—the pressure and the consequent metamorphism have been so great that in some varieties called anthracite no trace of the original vegetable structure can be detected even with the microscope. This, indeed, may be likened to the metamorphosis of sedimentary into crystalline rocks. Daubrée has actually proved by experiment that wood may be converted into anthracite by being exposed to the action of super-heated water at a very high temperature.† Other chemical researches—those of Liebig and Bischoff in an eminent degree—prove that the longer this evolution of carbonic acid goes on, the further does the wood depart from its ligneous form. First it gets converted into lignite, then into true bituminous coal, and then, aided by the metamorphosing agents mentioned, into anthracite.

That the vegetation entering into the composition of coal grew on land, is proved by the fact that, no matter what variation any seam may present, it has usually an underclay, which underclay — or fire-stone, fire-bricks being made from it—contains the roots of the plants of which the coal is composed. In short, it was the soil in which they grew. In this underclay also are found great quantities of *Lepidostrobi* (p. 103), which dropped to the ground from trees on which they grew, while athwart the coal seams are the trunks of the Sigillariæ converted into sandstone (Fig. 85). Unnumbered eons ago these ancient trees crashed amid the tangled vegetation of which they formed a part. Yet, as if showing how eternal are the laws of Nature, every now and again a miner is hurt, or killed by a "coal pipe," as he calls it, dropping on his head from the seam on which he is working. It came under the influence of the law of gravity millions of years ago; the pick of the collier loosens the fossilised vegetation around it, and instantly the arrested law resumes its operation by the trunk falling to the floor of the coal pit. Sometimes, within the area of a quarter of an acre, as many as seventy-three trees with their roots attached have been found, showing how dense were the jungles, the decay of which gave origin to the coal seams. The coal is covered with shale formed of the mud which gathered over the fallen vegetation, and yet, though some coals are worse than others, the absence of earthy particles and sand from their substance is remarkable. This purity, Sir Charles Lyell suggests, may be due to the upper layers of the fallen vegetation filtering and clearing the muddy waters which overwhelmed them of any mechanical impurities, just as the Mississippi floods are strained of sediment when they invade the dense thickets of vegetation on each side of the river. Hence, when a fire is lit in a dry portion of a Louisiana "cypress swamp," pits are burnt into the ground many feet deep without more than a small amount of earthy matter being left

* Ramsay: "Physical Geology and Geography of Great Britain," p. 566.

† Namely, 400° C. = 752° Fah.

behind. At the bottom of all of these swamps a bed of clay is found with the roots of the tall cypresses permeating it, just as the underclays of the coal beds are filled with stigmariæ. The varied qualities of coal which render it suitable for so many purposes depend, no doubt, on the varied composition of the vegetation which originally entered into its mass. Hence, one seam is good for the gas manufacturer, another is in favour for raising steam, a third immediately over it is in demand for smelting, while a fourth is estuaries, where they got covered with deposits of sand and clay, in which the molluscs of the superincumbent water would live and die, as must have been the case when the "mussel band" immediately above the "splint" coal in the Smeaton Pit, near Edinburgh, was laid down. This structure contains a layer of *Anthracosia*, a genus of shells allied to the fresh-water mussel or *Unio*, three inches thick, while the black-band ironstone of North Staffordshire is crammed with shells of *Anthracomya*, etc. It is also possible that,

Fig. 87.—BEDS OF COAL LYING BETWEEN LAYERS OF UNDERCLAY.

of commercial value mainly for burning in domestic grates (Fig. 87).

The facts mentioned in these pages force us to the conclusion that coal is the carbon of the vast forests (Figs. 88, 89) which grew on the shores of Carboniferous lagoons, in much the same way that peat is forming at the present day. Indeed, while anthracite may be regarded as the extreme form to which vegetation, placed under the conditions indicated, may attain, peat may be looked on as coal in its most elementary shape (Vol. I., pp. 60-63). Only, during the Carboniferous Period the vegetation was ranker than that which prevails in the regions where peat accumulates. No doubt some accumulations of coal might have been due to drift vegetation, masses of trees and herbage dislodged by floods and swept down into lakes and in a few isolated cases, coal-beds may have been formed of material drifted from a distance on the surface of lakes or the sea. But this theory is applicable in only a small number of instances—the purity of the coal, the very uniform thickness of a seam, and the perfect condition of the delicate plants associated with it, forbidding the acceptance of any such theory. Moreover, when, as in the South Wales coal-field, every one of eighty distinct seams of coal has under it an underclay—a semi-argillaceous deposit mixed with sand, from which fire-bricks are made—each of them permeated with the roots of Sigillariæ, it is clear that these seams were formed of vegetation which grew on the spot (Fig. 87). Some detached coal basins may have been formed by masses of river-borne vegetation, like the "Sudd" or "El Gett," which has at different

times choked up the current of the White Nile and several of its tributaries on the stretch between Khartoum and Gondokoro. The Kir, the Bahr al Ghazal, and the Sobat,

Fig. 88.—RESTORATION OF SPHENOPHYLLUM (A PLANT OF THE COAL MEASURES).

have all been at intervals so obstructed by these densely-jammed masses of drifted vegetation, that navigation has been impossible until the dams were cut through, at an immense cost in time, labour, money, and human suffering.* But, though we might picture to ourselves a vast drift of vegetation like these "getts," or of trees like those which sometimes accumulate in the American rivers, sinking to form a comparatively thin patch of coal, it becomes too much for the imagination to suppose that a coal-field 200 miles square —which is the size of that of Newcastle—or still less one of 14,000 miles square—the area of the Pittsburg seam in North America—could have been formed of drifted vegetation. The British and many other coal-fields (Vol. I., p. 59) lie in more or less isolated basins, but in all probability many of these basins were at one time, before they were broken up and separated from each other by disturbance of the strata and subsequent denudation, portions of one continuous deposit. Thus, according to Ramsay, north of South Wales and Dean Forest, all the other coal-fields of England, and perhaps of Scotland, were probably at one time a single coal-field, though now separated from each other by disturbances which threw their strata into long anticlinal and synclinal curves. The Staffordshire, North Wales, and Lancashire fields were certainly one. These, again, were conjoined to the Warwickshire, the Leicestershire, and Nottingham and Derbyshire coal-fields, which, again, were united with that of Durham and Northumberland, and these, by a further continuation, with those of Cumberland, and likely enough of Scotland.

Exhaustion of the Coal-Fields.—The coal-fields of the world at large are so enormous that it is unnecessary, for the present, to discuss the possibility of a time coming when the supplies of underground fuel will be unequal to the demands upon them. But in Great Britain commercial prosperity is now so bound up with coal-mining and the endless industries dependent on it, that more than one anxious inquiry has been made whether, and that before very long, a period may not arrive when there will be no more coal in these islands to dig, or when the cost

* These "getts" are described by Baker in his "Ismaïlia" (1874), and by Marno in Petermann's *Geographische Mittheilungen*, 1881 and 1882.

of "winning" it will exceed the market value of the fuel so laboriously obtained from the depths of the earth. The entire coal-pit population of Great Britain averages between 500,000 and 600,000, working in between 4,000 and 5,000 different collieries. In the year 1886 they raised 157,518,482 tons of coal, valued at £38,145,930; though in 1883 the output was 163,737,327 tons, worth £46,054,143. Again, as showing the oscillation in prices, the returns for 1881* were 154,184,300 tons, valued at £65,528,327. The question, therefore, comes to be —How long is this consumption to go on without the end of the deposits being reached? To enable the nation to arrive at some idea of how rapidly it is expending its capital, a Royal Commission was appointed in 1866, with the following results.† Taking 4,000 feet as the depth beyond which it is barely practicable to work, the amount of *visible* coal (the coal near the surface) in 1870 was 90,207,000,000 tons, an accumulation which has been considerably reduced since that date, while the *concealed* coal-fields (the coal covered deep by the Permian and newer formations) was estimated at 56,273,000,000 tons. Accordingly, taking the average rate of consumption at 150,000,000 tons per annum, and allowing for seams under two feet in thickness, and therefore unworkable, we have no more than nine hundred years' supply upon which to reckon. This, it may be admitted, is a reasonable duration for a nation's prosperity. In any case, with nine hundred years to look forward to, Cassandra may for a time postpone her wailing; for a great many things will happen in nine hundred years, or, if we accept the somewhat exaggerated estimates at which the population will increase, and the demand for coal *pari passu*, in a fifth of that period.

Still, there is no denying that every ton of coal brought to the surface, sold, and burnt is gone, never by any possibility to return.

Fig. 89.—CARBONIFEROUS FERNS RESTORED.
A, Arborescent ferns; B, Herbaceous ferns.

It is dissipated into its component elements, so that in a year we are consuming what took unnumbered ages to accumulate. Coal-mining is a comparatively recent industry in England. Though the Romans knew of its value as a fuel (for we find cinders by the side of their forges along the line of the Great Walls), it was not until railways and canals enabled the produce of the mines to be carried cheaply

* "Mineral Statistics of Great Britain and Ireland" (1886 and previous years).

† "Report of the Royal Coal Commission," three vols., with Atlas (1870); Jevons: "The Coal Question" (1866).

into all parts of the country that the coal trade assumed anything like the vast proportions with which we are familiar. When the Weald was covered with forests, Kent and Sussex were iron-smelting districts; the slag of the furnaces and the old dams which supplied the water to drive the water-wheels of the forges can be seen to this day. Tradition has it that the cannon cast to fight the Spanish Armada came from this district, and it is quite authenticated that the rails round St. Paul's and other of Wren's London churches were hammered out of Wealden iron. As late as the middle of last century there was a furnace at Ashburnham; and even half a century later so small were the demands of the ironmasters on the coal-fields of England that the annual output was not more than 10,000,000 tons per annum. At present we raise, use, or sell, considerably more than half of the coal mined throughout the world. However, we must not calculate on this always lasting. On the Continent of Europe there are coal-fields only partially developed, while the probability of petroleum being before long employed for steaming and other purposes for which, at present, coal is alone applicable, may greatly change the aspect of affairs. The electric light will largely supersede gas for illuminating purposes, though no doubt, as a force-raiser, coal or its equivalent must still be in demand. In America even, where no such alarm as that which we have discussed has ever troubled the national mind, natural gas (Vol. I., p. 142) has, in the Pittsburg iron district, largely taken the place of artificial gas for lighting, and of coal for smelting and glass-making. It is found also in most parts of Pennsylvania west of the Alleghany Mountains, extending to New York, Ohio, and West Virginia, as well as to a more limited extent in Kentucky, Indiana, Illinois, and Kansas. About one pound of coal is equal in value to seven and a half feet of this natural gas. The result is that, wherever found, iron and other goods, for which fuel is required, can be manufactured more cheaply than when coal is alone to be had. This gas has been found in China also, and in Austria the coals in the vicinity of Ostrau (p. 91) are so full of it that it finds its way into the cellars of the houses in the town. In addition, these coals give off large quantities of fire-damp * in the workings. In 1852 a bore-hole of 150 feet in depth gave off a stream of gas which was ignited at the surface, and has continued to burn with a huge flame to the present hour.

It is likewise within the bounds of possibility that, before we are compelled to tap our deep-lying beds, and face the difficulties of mining at a depth of 4,000 feet or more, new fuels may be discovered, and coal thus rendered of secondary importance. Coal, we know, lies deep down under beds of newer strata, the dip of the beds having caused it to take a dive beyond our reach, or, in the changes which the earth has undergone, the strata deposited over it have remained undenuded. In the plain of Cheshire, for example, the top of the Coal Measures is estimated to be 10,000 feet below the surface, Triassic and other beds being required to be bored through before it can be reached.† To mine at this depth would be impossible, unless Science works wonders between now and the time when we may be forced by necessity to essay so desperate a venture. And, even could flesh and blood endure it, the cost of "winning" coal at such a depth would make fires most expensive luxuries. The Northumberland and Durham coal-field extends under the sea, and in various places in the vicinity of Sunderland, and more especially at Ryhope and Monkwearmouth, is worked at a depth of from 1,200 feet to 1,850 feet to a short distance from the shore. In other words, the seams at the latter spot

* Light carburetted hydrogen, which, when diffused in the atmosphere of the coal-workings to the amount of one-thirteenth by volume, becomes explosive if light is applied. The after-damp or "choke-damp" is the resulting carbonic acid, which does most of the mischief by suffocating the imprisoned miners.

† There is some likelihood of a coal-field lying, deep down, between South London and the line of the North Downs or Surrey Hills. Mr. Etheridge has discussed the question in his *Presidential Address to the Geological Society*, 1881, and Mr. Drew in "Science for All," Vol. V., pp. 324–328.

(Monkwearmouth), are worked more than nine times as far under the ground as the London "Monument" is reared above it, or more than five times as low down as the Cross of St. Paul's is high up. Yet this is not the deepest vertical mine in Great Britain. This distinction is claimed by the Ashton Main Colliery at Ashton-under-Lyme, which in 1881 was 2,692 feet from the surface, and will be sunk still deeper. At Hainault in Belgium coal is worked at the depth of 2,800 feet, and one pit has been sunk as far down as 3,411 feet. The deepest coal-shafts in America are those near Pottsville, in Pennsylvania; they are nearly 1,700 feet from top to bottom. At the depth of 1,800 feet the average temperature, apart from that produced by the heat of the lamps and the breathing of many men, is close on 80°. In the Ashton shaft the coal at the bottom shows a heat of 86°, which is lower than what might have been deduced from observations made in shallower mines. At 4,000 feet — and experienced miners have not hesitated to say that work is possible at even a greater depth—the temperature of the air must be fully as high as that of the blood, so that, even if the pressure of so great a column of air could be overcome, it is hard to see how labour under anything like economic conditions is attainable so far beneath the surface. Even in the comparatively shallow mines of St. Day, in Cornwall, the bottom temperature mounted as high as 120°, and work was possible for only fifteen minutes at a time, or for three hours daily.

Accordingly—though, as matters now stand, it is only a question of centuries when the British coal-fields, or, indeed, those of Europe, will be exhausted of the fuel which can be easily reached—there is no cause for immediate alarm. Every age is equal to its own necessities. Thus, in a thousand years the pivot on which commerce turns may no longer be cheap fuel or cheap labour. The subterranean fires may be utilised. The all-bountiful sun may furnish the motive-power for machinery direct. Already, indeed, solar engines promise great things. If so, the Northern or the Southern hemisphere of either the Old or the New World will not be the scene of manufacturing industry, but the damp jungles and torrid deserts of the Tropics; not Lancashire and Massachusetts, but Africa and the Sahara.*

Permian System.

At the top of the Palæozoic rocks lies a series which seems to have been deposited after the consolidated beds of the Carboniferous System had been uplifted and dislocated, since it is on their denuded edges that we frequently find those which succeeded them. Generally, they repose not quite in conformity either with the underlying Coal Measures or with the overlying Triassic System, though in the north-east of England, in the county of Durham, they are conformable to, and appear to be a continuation of, the Carboniferous System. Accordingly, they have sometimes been classed with the latter, and sometimes with the beds which

* In addition to the memoirs and volumes already mentioned, the following selection from the extensive literature of the Carboniferous System may be studied:—Hull: "Coal-Fields of Great Britain" (1873) and the Reports of the Geological Survey on the different coal-fields; Galletly: "Coal" (British Manufacturing Industries); André: "Practical Treatise on Coal-Mining" (1876); Smyth: "Coal and Coal-Mining" (1872); Macfarlane: "Coal Regions of America"; "Tenth Census of U.S.A.," Vol. XV. (1875); Rogers: "Geology of Pennsylvania" (1850); Sheafer, in *Encyclopædia Americana*, Vol. II., pp. 159–286; Burat: "Cours d'Exploitation des Mines" (1871); Ponson: "Traité de l'Exploitation des Mines de Houille" (1868–71); Geinitz: "Die Steinkohlen Deutschlands" (1865); Zincken: "Die Braunkohle" (1865–71); Brady: "Monograph of the Carboniferous and Permian Foraminifera" (*Palæontographical Society*, 1876); Boulay: "Terrain Houillier du Nord de la France et ses Végétaux Fossiles" (1876); Grand'Eury: "Flore Carbonifère" (1882); Schimper: "Traité de Paléontologie Végétale" (1874 *et seq.*); Zittel: "Handbuch der Palæontologie" (1879); Lindley and Hutton: "Fossil Flora of Great Britain" (new edition); Kidston: "Catalogue of Fossil Plants in the British Museum" (1886); Dawson: "Geological History of Plants" (1888); Schenk: "Palæophytology" (1887, *et seq.*); and numerous papers by Lesquereux, Göppert, Dawson, Newberry, and others, in various publications; but particularly, so far as British geology is concerned, those by Carruthers, Kidston, Young, Traquair, Nicholson, Thomson, Duncan, and Ricketts, in the Proceedings of the Geological Societies of London, Edinburgh, Glasgow, and Liverpool, and of the Philosophical Society of Glasgow, 1876, 1877, 1880, 1881, 1882, etc., etc.

form the Trias or New Red series, so that they may be regarded as a kind of debatable system—a transition series—between the close of that very ancient period of creation (the records of which exist in the various Palæozoic beds) and that which began with the Mesozoic Age (Fig. 90).

In the British Islands the Permian consists of red conglomerates, marls, dolomitic limestones, and sandstones, in the lower part of the System, and of sandstones and conglomerates in its upper division. A glance at the geological maps of Great Britain and Europe will show the districts in which these geological features prevail, though nowhere in Great Britain is the Permian the marked feature it is on the European Continent. In the Russian Government of Perm, the system is, for example, very decidedly developed. Hence the name applied to it by Sir Roderick Murchison. In Germany, again, in the Harz and the Thuringian Forest for example, it is markedly divisible into two great series, a lower or *Rothliegende*, and an upper or *Zechstein*, the first consisting of reddish conglomerates, sandstones, and shales, with dolomite, bituminous shales, and occasional irregular beds of limestone; while the second, which corresponds to the Magnesian Limestone of Great Britain, comprises the *Zechstein* proper and the *Kupferschiefer*, or the equivalent of our marl slates. Hence, from this two-fold division, the term *Dyas* is commonly used to designate the Permian, this name having of late begun to be used in England also.*

Fig. 90.—IDEAL LANDSCAPE OF THE PERMIAN PERIOD.

* Greek, *duas*, duality. This name is perhaps more appropriate than Permian (Murchison's classification of which was erroneous); but for the present it is as well to keep to the older name. *Rothliegende* means "red layer," while *Rothtodltiegende* or "red dead layer," which is also applied to it by the German miners, refers to their ores disappearing in the red rocks below the Kupferschiefer, or "copper shales." *Zechstein* means

From Germany, the Permian stretches into France, and over the Alps into Italy (in the shape of the so-called "veruccano" near Pisa). In North America the Permian is well developed in Kansas and other regions west of the Mississippi, where, as in Europe, it consists of conglomerates, sandstones, limestones, and marls, with beds of gypsum—all these beds being of marine origin—graduating, without any unconformability, into the Carboniferous below, so that it is usually described as "Permo-Carboniferous," might have been drifted, of a decidedly marine origin. Altogether little more than 600 species are known, this scanty list exhibiting a terrible impoverishment since the exuberant life of the Carboniferous Period.

The general *facies* of the flora and fauna of all the formations entering into this system is markedly Palæozoic, though we no longer find many of the genera which were abundant in the Carboniferous Age. Yet *Calamites, Lepidodendron, Chrondites, Ullmania, Cardiocarpum, Alethopteris, Sphenopteris, Neuropteris, Pe-*

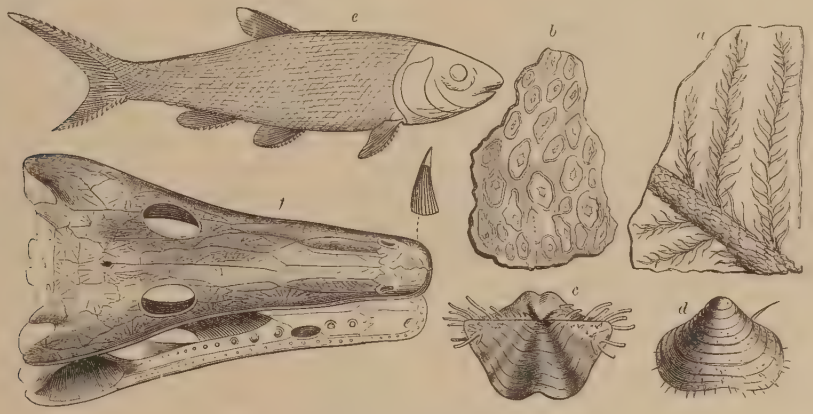


Fig. 91.—FOSSILS OF THE PERMIAN SYSTEM.

a, Walchia piniformis; *b*, Psaronius asterolithus (the "staarstein" of the German peasants), a tree fern cut across; *c*, Productus horridus; *d*, Strophomena excavata; *e*, Palæoniscus freieslebeni; *f*, Archegosaurus decheni (the skull with tooth, half the natural size).

no distinct division existing between the two systems.

Life of the Permian System.—The fossils found in the Permian beds are not, as a rule, abundant (Fig. 91), and are chiefly contained in the limestones and the greyish shales of the upper members of the group. Those which have been disinterred from the lower Permian are principally land plants and footprints, believed to be those of labyrinthodonts (p. 98), while the remains in the upper group are, with the exception of a few terrestrial plants which *copteris*, etc., are still represented by a number of new forms, and various fragments of coniferous wood indicate the existence of trees of the pine and fir Order. About fifty species are common to it and the Carboniferous. On the whole, however, the exuberant flora of the Coal Measures is decidedly on the wane, the forms found bearing the impress of being impoverished descendants of more stalwart ancestors. The Lepidodendrons are no longer so profuse, and the rank Sigillarias, though they linger on, die out with the Permian Age. Ferns are the most common plants. *Callipteris* is the most notable of the new genera which have appeared, or which, at least, have not as yet been detected in the Coal Measures; *Psaronius* was a tree-fern (Fig. 91, *b*), and

"mine stone." Possibly, as Von Buch suggests, the word comes from the Italian *zecchino*, a sequin, a coin at one time well known in Germany, because the zechstein, or magnesian limestone, was the cover which, being probed, enabled them to get at the ore in the Kupferschiefer, from which their profit came.

among other conifers, *Walchia* (Figs. 91, *a*, 92) is represented by a characteristic species. *Araucarites schrollianus* was another conifer, which seems to have grown densely in the Permian forest of Radowenz, in Bohemia, in company with such palms as *Medullosa* and *Porosus*, and great cypresses like *Ullmania bronnii*, etc.

Polyzoa, echinodermata, and other lowly forms, are still numerous, though, with few exceptions, belonging to genera of Carboniferous, or even earlier date. But the trilobites have vanished, and the once-abundant king-crabs are represented by but one species, though, to make amends for their absence, the short-tailed crustacea, belonging to the same group as our edible crabs, now, for the first time, begin to appear. Mollusca are plentiful, though brachiopods are decreasing, and the once plentiful cephalopods, or cuttlefish in shells, have dwindled away, until the only genera of the old type found in the Permian rocks are *Orthoceras* and *Nautilus*. Fishes are, however, not unfrequent, particularly in the Kupferschiefer of Germany, and in the marl slates of England, the chief genera being *Palæoniscus* (Fig. 91, *e*) and *Platysomus*, though, as in the former ages, they belong almost entirely to the Ganoids.

Fig. 92.—WALCHIA SCHLOTHEIMII.

Amphibian reptiles are plentiful, and the marks of their footprints abound on rocks, which seem to have formed in their soft state the slimy shores of the Permian lagoons. All of these appear to have belonged to the somewhat heterogeneous group of Labyrinthodonts. *Dasyceps bucklandi* from the Red Permian of Kenilworth, *Lepidotosaurus duffii* from the base of the magnesian limestone, and *Archegosaurus decheni* (Fig. 91, *f*) from the marly beds of Lebach in the Saarbrück Basin, are among the most remarkable of the forty or more species which have been described. In the Vale of Eden, at Brownrigg, Plumpton, and Penrith, numerous footprints have been found, and they are frequent on the surface of beds of sandstone on Corncockle Muir, and in other parts of Dumfriesshire, the crystals of salt and gypsum deposits, together with the sun cracks and rain pittings, telling in fuller detail the story which the footprints relate. But, as a German geologist has remarked, the *Archegosaurus decheni* was the "stammvater der Saurier": its structure indicates an approach to those true reptiles of which the amphibians may be regarded as the progenitors. This "stammvater," or "ancestor of the Saurians," leads on by a regular series of links to *Proterosaurus*, a genus of true lizard-like reptiles with well-developed limbs, and which, though small compared with some of the species still to appear, was fully three or four feet in length, its general appearance being something like that of the modern monitors of Egypt. The salamander-like *Branchiosaurus* (two and a half inches long), which Fritsch has described from the Moravian and Bohemian Rothliegende, was perhaps more a true reptile than a batrachian. The *Theriodonts* were probably the lizards which made the footprints in the Permian sandstones of Scotland (though these have been referred to tortoises, no species of which appears until a much later period); and Cope has described, from the Permian of Texas, reptiles* having many of the characteristics of the Theriodonts, combined with those of the herbivorous mammals. Not only was their dentition divided into incisors, canines, and molars, and the teeth all set in sockets, but they were possessed of flat grinding teeth, believed to indicate the vegetarian habits of these curious reptiles.

The Permian World.—The unconformity which marks the division between the Carboniferous and Permian Systems in many parts of the world, hints broadly at a troubled condition of the Earth during the period immediately antecedent to the deposition of the beds just described, while the volcanic rocks which interstratify with and penetrate them point to the Permian Age being one of

* *Diadictes* and *Bolasaurus*.

an unsettled character. Inland lakes or seas formed, while the water disappearing off large sections of the globe (covered during the Carboniferous Period) laid bare a greater area than had hitherto appeared above the surface. Melaphyre, porphyrite, and other igneous outbursts, are common, both in Germany and Scotland. Indeed, it has been suggested that the well-preserved character of the fishes in the Kupferschiefer, is due to their having been suddenly killed by the waters in which they swam being poisoned by exudations—gaseous or liquid—which we know are the ordinary accompaniments of volcanic eruptions. In any case, it is probable that the Permian rocks were deposited in basins disconnected from the ocean, either permanently or with the exception of short intervals, the character of the strata, leaving the thicker limestones out of account, being that of beds which had formed in inland seas like the Aral or the Caspian. That these basins must have been of considerable size, is proved by the extent which the deposits in question cover. In Russia, for example, the Permian System—conglomerates, sandstones, shales, rock-salt, gypsum, and other seams of coal and limestone—occupies an area of over 15,000 square miles. It may be added that all the Permian shells present a dwarfed aspect, such as might be expected from species living in brackish or impure water. In this respect Ramsay regards the fauna as comparable to that of the Caspian, a lake now shut off from any sea, though, from the marine forms which it contains, believed to have been at one time open to the Northern Ocean. Indeed, did tides exist in the Black Sea, the Caspian would be liable to be invaded by the waters of that sheet during spring tides.

The red and variegated sandstones, the dolomitic limestones, and the gypsum and rock-salt, are materials which would be likely to be laid down in such a land-locked basin, under such circumstances that "carbonates of lime and magnesia were deposited simultaneously, probably by concentration of solutions due to evaporation." In the Carboniferous formations such masses occur, but far less sparingly, since in the open ocean "lime and magnesia only exist in solution in very small quantities, and limestone rocks are there formed, as in coral-reefs, by organic agency."

During this age—as, indeed, during almost every period of the world's history—ice seems to have played a more or less active part. Some of the Permian breccias in the Midland Counties of England contain boulders which can be traced to the Silurian rocks of North Wales, and might have been borne that distance by ice, either floating or in the shape of glaciers, while the presence of many striated blocks has led Ramsay to conclude that there was a "Glacial period" during the age of which we have sketched the leading characteristics. It is also not unlikely, as Dr. Hull suggests, that about this epoch the Atlantic continent, which had stretched between what is now Europe and America, got broken up, submerged, and, in part at least, converted into the open ocean it afterwards became. During some of the earth-throes of the Permian Age Europe began to assume shape, so far as a continuous stretch of land was concerned, while the Pennine Chain, the backbone of England, dates its appearance from this time. Into these hypothetical questions it is, however, impossible to enter. They are fully discussed in more technical publications.* It is, however, certain, from the great thickness to which many of the Permian deposits reach, that the period during which they were formed must have been one of long duration. In the West of England the various beds entering into the System are between 3,000 and 4,000 feet thick; in Bavaria they are 6,000 feet or more; even in France they attain a thickness of fully 3,000 feet.

Scenic and Economic Aspects.—Owing to the comparative absence of great igneous

* Hull: "Contributions to the Physical History of the British Isles" (1882); and *Quarterly Journal of the Geological Society*, Vol. XXV., p. 171; Wilson and Teall, *Geological Magazine*, Vol. VI., p. 500, and Vol. VII., p. 349; Göppert: "Die Fossile Flora der Permischen Formation" (1864-5); Fritsch: "Fauna der Gaskohle und der Kalksteine der Permformation Böhmens" (1881 *et seq.*); King: "Monograph of the Permian Fossils" (*Palæontographical Society*, 1850); Murchison, Verneuil, and Keyserling: "Russia and the Ural Mountains" (1845); etc. etc.

dykes and knolls like those characterising the Carboniferous System, the Permian is, on the whole, somewhat tame from a picturesque point of view. As the neighbourhood of Shrewsbury and the eastern portions of Durham show, rounded hills and gentle slopes are the most striking features of a Permian country, the strata being soft, and therefore easily eroded by rivers and other denuding agencies. In Russia the Permian beds lie nearly horizontal. In Germany they are more varied. The Wartburg near Eisenach, and the Kyffhauser south of the Harz, are, for instance, famous points where the Permian (Rothliegende) is found well developed, the beds containing much silicified wood.

The economic importance of the series is, however, more marked. The magnesian limestone often makes a good soil, though the red clayey loam formed by the disintegration of the marls and sandstones is less fitted for grain. Hence pasturage and woodland most frequently cover it. The copper impregnating the dark bituminous schists, which derive their name (Kupferschiefer) from this circumstance, have long been mined in Germany. In the Harz, Bohemia, Autun, the Schlau-Rakonitzer, and Pilsener districts, the Schalzlarer and Rossitzer districts in Austria, and other localities, there are seams of coal, one of which, in the Rothliegende of the Mansfeld District of Bavaria, is about five feet thick. The Upper Coal Measures of New South Wales, comprising seams from eight to twenty-five feet thick, have, like some of those of India, been classed as Permian, though there are good grounds for believing that these, like the others already spoken of, are Carboniferous. In Russia also there are thin Permian coal-beds, and those of Tonkin are now regarded as of the same age.* Galena and sulphuret of zinc are sometimes found in veins traversing the magnesian limestone, and the gypsum, when found in sufficient quantity—as in the "Gypsschlotten" of the Harz, and in the salt region of Stassfurt (Vol. I., p. 276)—is dug for economic purposes. The magnesian limestones are held in esteem as building stones, those of Bolsover being the material out of which the Houses of Parliament in London are built, though they are too variable to be extensively employed, some being lasting, while others—as has been too frequently the case in the buildings mentioned — crumble to such an extent as to need continual re-facing. The sandstones and conglomerates furnish local building stone, and the limestones are burnt for mortar, while some of the more compact, fine-grained fissile varieties have been tried with some success as lithographic stones. The dolomites of the North of England are used for the production of carbonate of magnesia and, by being treated with sulphuric acid, for the purpose of obtaining Epsom salts or sulphate of magnesia. Some of the principal salt deposits of Germany—that of Stassfurt, for example—occur in beds of magnesian limestone.

* Sarnan : "Etude sur le Bassin Houiller du Tonkin" (1888).

Fig. 93.—IDEAL LANDSCAPE OF THE MUSCHELKALK.

CHAPTER VIII.

The Mesozoic Rocks: The Triassic System.

What Distinction exists between the Palæozoic and the Mesozoic Periods—The broad Characteristics of the Forms of Life prevailing during these great Epochs—The Changes which the World had undergone during the Palæozoic Epoch—The Triassic—Wherein it Differed from the Permian—Its Distribution and Classification, with the chief Foreign Equivalents of the British Divisions—The Alpine Trias—The Life of the System—Appearance of the Ammonites—Batrachia (Amphibia) and Reptiles—First Appearance of Mammals and of supposed traces of Birds—The Microlestes and the Dromatherium—Physical Geography of the Period—Its Scenic and Economic Aspects—The Formation of the Beds in Inland Lakes or Seas, like the Caspian or the Great Salt Lake of Utah—The Rhætic Deposits and the Alpine Trias formed under different Conditions—A Sort of Transition Period indicated by these Deposits—Short Stretch of Time occupied in laying them down compared with that concerned in the accumulation of the preceding Systems—Climate of the Period presaged from the presence of Cycads—Wide Range of Species—Volcanic Outbursts—Scenery tame—Soils often poor—Effect of this on the Distribution of Forest and other uncultivated Lands—Building Stones—Coal—Salt—etc.

With the Permian closes the Primary or Palæozoic Epoch, and with the Triassic begins the Secondary or Mesozoic Age of the Earth. Yet, from the difficulties experienced in classifying the System last described, it will be seen that the break between it and the Triassic is not very defined, and, consequently, the gulf between the first and the second great stages of the World's history is less marked in the closing period of the one and the opening one of the other, than in the broad characteristics which distinguish the two. Indeed, several of the beds which now come to be described, were, not many years ago, included in the

Permian. There is a break in the palæontological sequence of the formations, though this is not so abrupt as was at one time supposed to be the case. Still, the change from the old-world type of the Palæozoic rocks to the newer-world type of the Mesozoic series is soon very marked. The species of plants and animals continue to be widely different from those prevailing at the present day, and some are even more bizarre than the forms whose acquaintance we have already made. But they are gradually approximating to what has been termed the Neozoic or new life shapes, so that the palæontological differences between the Age now to be considered and that which has passed away is far greater than between the former and the Tertiary and Quaternary epochs which close the geological record. The cystoid and blastoid echinoderms are replaced by true sea urchins of the types with which we are more familiar. The trilobites vanish in favour of the more ordinary decapod crustaceans. The orthoceratites give way to the ammonites and belemnites, and the rugose corals are replaced by others differently fashioned. Instead of having their septa arranged in fours, those of the Ages now to be considered have these ray-like partitions arranged in sixes. The Palæozoic cuttlefishes seem for the most part to have had no sucking discs on their arms; those of the Neozoic periods are generally furnished with them. The old world species had also the sutural junctions of their chambered shells plain and simple; those of the coming times had them often foliated into the most intricate patterns (Fig. 40). The Palæozoic crustacea seem, compared with the Neozoic ones, less developed. They are, in brief, more larval-like, the division into head, thorax, and abdomen, being less marked. The fishes also, instead of having their tails unequally lobed (p. 49), which is a characteristic of the lower type of forms and of the embryonic condition of fishes in general, have them for the most part equally divided.

This passing away of graptolites, cystideans, trilobites, and eurypterids, of armour-covered fishes, and of strangely-shaped corals, is accompanied by a change in the vegetable life quite as marked. No longer do we disinter from the strata, sigillariæ and lepidodendra: they were dying out in the Permian; they vanished before the Triassic began. Acrogens get scarce, and the development of vegetable life takes the shape of true flowering plants with netted veined leaves—forms which were never seen in the Palæozoic rocks. Birds and mammals now appear for the first time, and though many of them are of the most extraordinary character, it also is clear that the general structure is approximating more closely to that of modern animals than at any former period of the World's history. Creation has, in a word, advanced, just as we shall see that it advances in every System until it reaches the stage of vital evolution in which we live. Yet though the thicknesses of the Palæozoic strata are more than three times that of those which succeed them, in the former not much more than half as many species of fossils have been found as in the latter. Accordingly, unless deposition was much more rapid in the early ages of the World's history than in the latter, the Neozoic ages could not have lasted so long as the Palæozoic one.* During that period the world seems to have undergone wonderful changes. Oscillations of the surface were constantly in progress—a portion of land which at one period was above water being in that which succeeded it submerged; great inland lakes, such as those which prevailed in the Cambrian Age, giving place to the sea of the Silurian, while in the Old Red Sandstone Period, the lacustrine epoch seems once more, though in a different form, to have held its own in the north of Europe. The Carboniferous Age, however, effaced these inland seas, though before the close of the period the Caspian-like lakes which distinguished the Permian had again begun to form. The land from which most of the sediment out of which the Palæozoic

* The estimated thickness of the stratified rocks is as follows:—Palæozoic, 113,000 feet; Mesozoic, 15,000 feet; Tertiary, 3,000 feet; Quaternary, 600 feet.

strata were formed, would appear to have lain towards the north and north-west, so far, at least, as Europe was concerned. Land seems never to have been entirely wanting there, though the immense thickness of their deposits compels us to conclude that the Continent must during all that long period have stretched much farther into the Atlantic and the Polar Seas than it did at any subsequent period. The Atlantic—as the ocean we know it—did not exist until somewhat late in the Mesozoic epoch—if, indeed, there was not an Atlantis, or land-bridge from Europe to America, in Tertiary times—though as the beds in question bear the impress of having been laid down in seas of no great depth, the submergence of the terrestrial surfaces which was necessary for their accumulation must have proceeded gradually, with numerous pauses, and, as we have seen, not unfrequent retrograde movements; in other words, elevations of the bottom far above the surface of the ocean. What was all this time going on in other parts of the world can, for the present, be presaged only very imperfectly, as our acquaintance with the geology of other regions is not so complete as is our knowledge of that of Western Europe. In America, however, it may be said that during most of the Palæozoic epoch the land from which the sediment came was towards the north, and that, as in Europe, the land surface bordered southward as the Mesozoic period approached.

Triassic System.

Separated from the Permian System of strata by a distinct break in the shape of an unconformity, lies a series of formations which, from their taking a threefold arrangement, have been termed the Triassic.* Before they were laid down the strata which preceded them, and on the denuded and upturned edges of which they repose, must have been dislocated and metamorphosed, so that, in spite of their former classification with the Permian, it is certain that a long interval must have elapsed between the end of that System and the beginning of the one now under consideration.

This inference is strengthened by the fact that the fossils seen in the Trias are no longer of a Palæozoic type, and many forms characteristic of Mesozoic times now make their appearance. Most of the genera of brachiopoda have vanished, while not many genera, and no species, of bivalve shells, pass from the one System to the other. In Great Britain (*See* Geological Map) the Triassic strata, so far as they are developed in this era, are found in patches and strips from "Devonshire along the banks of the Severn, round the eastern borders of the Palæozoic rocks of Herefordshire and North Wales. From thence," says Ramsay, "they stretch eastward to the Permian and Carboniferous rocks of Lancashire, North Staffordshire, and Derbyshire. They surround all the Midland coal-fields and Permian beds between Shrewsbury, Coventry, and Derby, and from thence, everywhere unconformably overlying the Permian rocks, they stretch north in a long band from Nottingham to the River Tees." In short, they skirt the high lands of Wales and the north of England in a manner which leads us to conclude that, by the time they were laid on the underlying Carboniferous and Permian strata, the main features of these regions had already taken shape. In Scotland there are patches of Triassic strata in Skye and other of the Western Isles, as at one or two places on the mainland (Gruinard Bay, Ardnamurchan, and Morven, for example), while patches of red sandstones near Dunrobin Castle in Sutherlandshire, and at Elgin on the Moray Frith, as well as in similar small areas in Dumfriesshire, have been referred—though with some doubt—to the same Age; while the principal Triassic rocks of Ireland are seen in the valley of the Lagan from Lurgan to Belfast, from which point they stretch along the shore of Belfast Lough as far as

* In England this threefold arrangement does not exist, the middle member of the series being wanting. At one time these beds and the Permian were collectively known as the New Red Sandstone. This term is still occasionally employed, but only as a synonym of the Triassic system, though both names are open to many grave objections.

Ballycastle, though smaller tracts of a less pronounced character are found elsewhere —in Tyrone and Londonderry, for instance.

It is, however, in Germany (Fig. 94) where the Trias is best and most completely developed, the surface of the country between the Thuringian Forest and the Vosges Mountains, and between Basle and Hanover, being covered by them. North of Hanover they are partially concealed by newer formations. They also crop out in the red cliffs of Heligoland (Vol. I., Fig. 9, p. 28, and Plate), and in the south of Sweden, where they are associated with thin seams of coal, and contain a large number of land plants. In the Eastern Alps peculiar Triassic beds are seen. The System

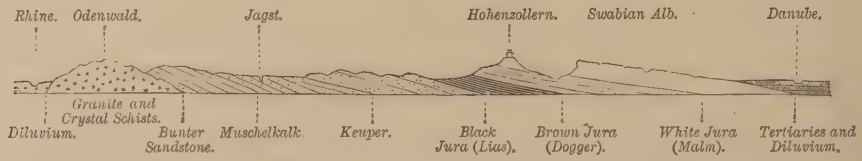


Fig. 94.—SECTION OF THE TRIASSIC AND JURASSIC DEPOSITS OF SOUTH-WEST GERMANY.

also appears in France, Spain, and Portugal; in America, between the Appalachian Mountains and the coast, as far north as Nova Scotia and Prince Edward's Island. In many of the Western districts, across the Rocky Mountains into Mexico, California, British Columbia, and Alaska, rocks apparently of that Age extend, though the sparsely fossiliferous character of these reddish sandstones and marls leaves their age doubtful. Spitzbergen has Triassic beds. So have the Himalayas and various parts of Australia, some of the coal beds of Queensland being most likely referable to that period.

The rocks consist for the most part of bright red or mottled sandstones, clays, or marls, interspersed with veins or nodules of gypsum, beds of rock-salt, and extensive beds of limestone.

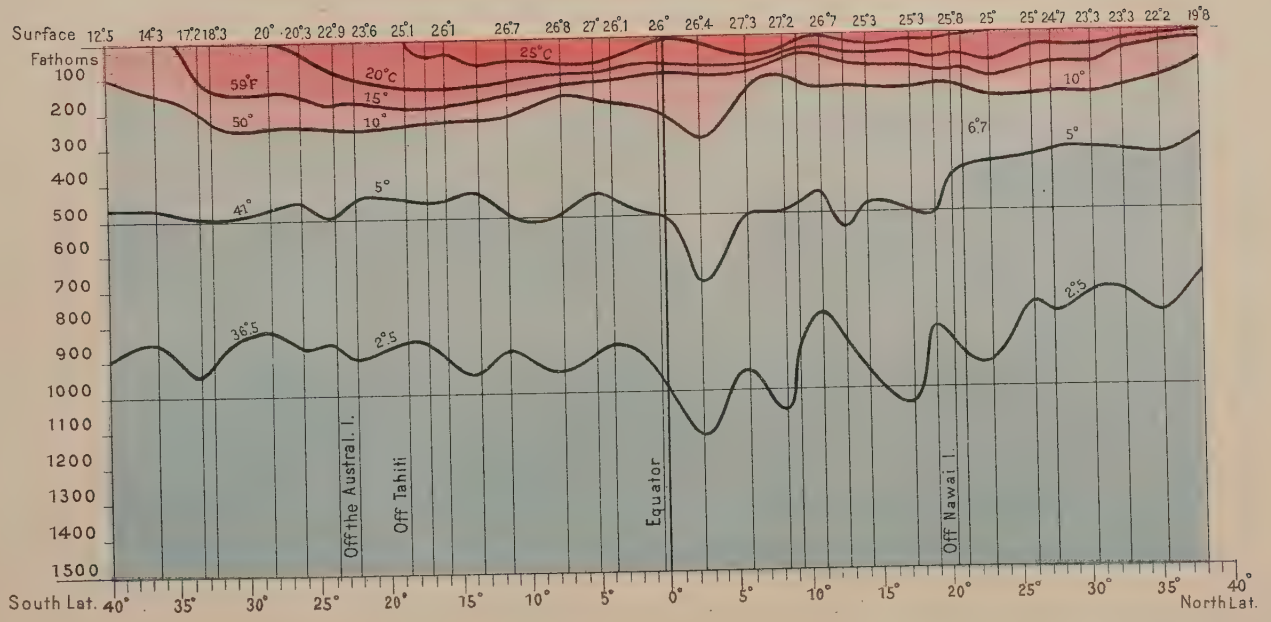
Classification of the Trias.—Owing to the Triassic System being most markedly developed in Germany, the different divisions of the System have received German names. The classification adopted is also that of the German geologists, though there is considerable doubt as to whether the Trias, as seen in other parts of the world—in England, for example—is not more normal than in the region in question. However, this is a point which we are not called upon to discuss. Accordingly, from below upward the beds have been divided into (1), The Lower Trias; (2), The Middle Trias; and (3), The Upper Trias.

(1) *The Lower Trias.*—This is commonly known as the "Bunter Sandstein," from the variegated or mottled colour of the beds which compose it,* though white sandstones, red clays (usually, though erroneously, described as marls), and dolomitic limestones, enter into the composition of the division to the thickness of fully 1,500 feet. In Britain the principal members of the Bunter Sandstein are the red and mottled sandstones, from which it takes the German name, and beds of loose conglomerate or gravel. The few fossils that are found in it are usually land plants, and the footprints and bones of Labyrinthodonts. In Germany one or two ferns, a few conifers (*Albertia* and *Voltzia*), a horse-tail (*Equisetum arenaceum*), etc., occur. *Myophoria costata*, a bivalve shell, is found in the upper division, and, in addition, the bones of fishes occur in it (Fig. 95).

(2) *The Middle Trias.*—This division is not developed in Great Britain, but in Germany, where it is known as the "Muschelkalk,"† extensive beds of grey or yellowish limestones, with included beds of gypsum and rock-salt, come under this head (Fig. 93). The lower portion is very sparingly fossiliferous, but the upper limestones (which vary in thickness from

* German *bunt*, variegated.

† German: *Muschel*, mussel, and *Kalk*, limestone; from the many fossil shells which it contains.



TEMPERATURES OF THE SEA IN THE PACIFIC, NORTH AND SOUTH OF THE EQUATOR

(IN DEGREES CELSIUS:)

FROM WILD'S THALASSA BY PERMISSION OF MARCUS WARD & Co, LIMITED.

550 feet to 1,100 feet) swarm with many animal remains, such as *Nautilus bidorsatus, Terebratula vulgaris, Myophoria cardissoides* (Fig. 95, 7), etc., with *Encrinus liliiformis* (Fig. 95, 3) in the lower and *Ceratites nodosus* (Fig. 95, 9) in the upper part of the rocks. Sometimes, indeed, the upper portion is entirely made up of crinoid stems, and is, therefore, an essentially marine formation; though where the principal development of the Keuper is seen. Here the series abound in land plants, such as *Equisetum columnare* (Fig. 95, 2), *Pterophyllum, Araucarioxylon thuringicum*, etc., with the remains of labyrinthodons and fishes, while the shales are crowded with a small crustacean (*Estheria minuta*). In England, however, the Keuper is almost devoid of fossils, and passes upward into a series of dark shales,

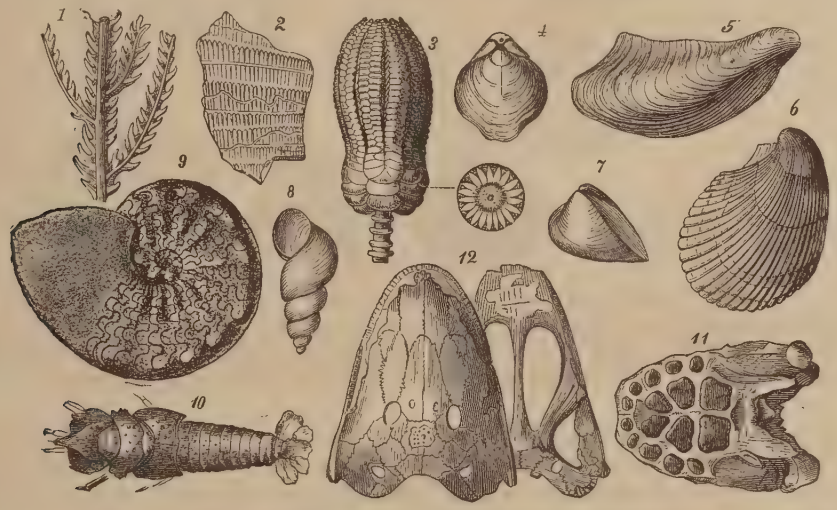


Fig. 95.—TRIASSIC FOSSILS.

1, Voltzia heterophylla; 2, Equisetum columnare; 3, Encrinus liliiformis (calyx and section of the stalk); 4, Terebratula (Waldheimia) vulgaris; 5, Gervillia socialis; 6, Lima striata; 7, Myophoria (Trigonia) cardissoides; 8, Melania schlotheimii; 9, Ceratites nodosus; 10, Pemphyx sueurii; 11, Placodus gigas (under surface of the upper jaws of a saurian reptile confined to the Muschelkalk); 12, Capitosaurus robustus (skull), from the Keuper.

in the middle portion, which otherwise is almost devoid of fossils, the bones and teeth of saurian—that is, lizard-like—reptiles like *Placodus* (Fig. 95, 11), have been found.

(3) *The Upper Trias.*—This division, known in Germany as the "Keuper" (Fig. 98),* owing to the fact that the red and variegated marls of which the upper portion of it consists are copper-bearing, is found in England in the shape of red and grey shales and marls, white sandstones, etc., with the usual layers of gypsum and rock-salt, to the thickness of from 800 feet to 3,500 feet. But it is in Germany grey and greenish marls, and grey limestones, which were at one time classed with the Jurassic System (which succeeds the Trias). They are known as the Penarth beds, from Penarth Head, near Cardiff, the *Avicula contorta* beds, from the occurrence in them of this bivalve (Fig. 96, 1), or the Rhætic, from the fact that they occur in the Rhætic Alps. Some geologists make them a distinct division of the Trias; but it is more convenient to retain them as simply transition beds, which lead into the Jurassic. This is their character in many places where they are found (and in Great Britain they occur in Gloucester, Glamorgan, Warwick, Stafford, and the north of Ireland), both in their fossils and their general

* German: *Keuper*, copper, an abbreviation for *Kohlen-Keuper* (coal copper), owing to the presence of a thin, earthy coal of little or no value (*Lettenkohle*).

position to the strata above and below them. In Fig. 96 the most characteristic of their animal remains are delineated. These consist of a cockle (*Cardium rhæticum*), the *Avicula*, (Fig. 97) the Trias terminates in an extensive series of fossiliferous beds, of which there are no exact representatives in any other part of the world, except that the upper members

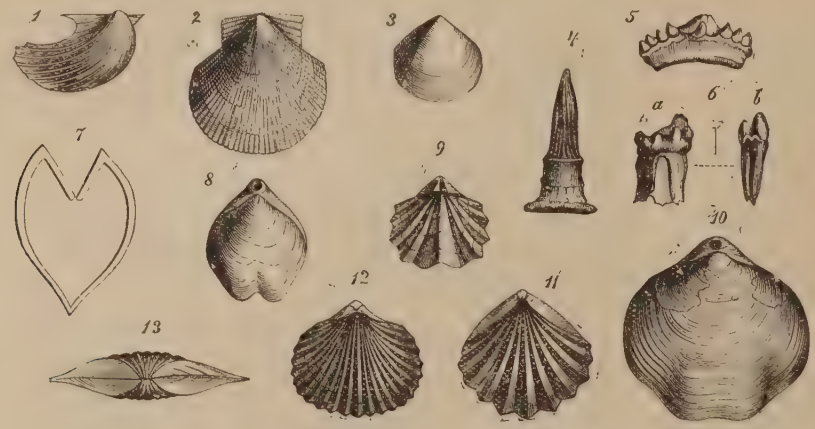


Fig. 96.—FOSSILS OF THE RHÆTIC BEDS OF THE TRIAS.

1, Avicula (Cassianella) contorta; 2, Pecten valoniensis; 3, Cardium rhæticum; 4, Saurichthys apicalis (fish tooth); 5, Hybodus (fish tooth); 6, Microlestes (Hypsiprymnopsis) antiquus (back tooth—two views, *a* and *b*, the upright line between the two showing the actual length of the molar); 7, Cardium (Dicerocardium) triquetrum (section); 8, Terebratula gregaria; 9, Spirifer münsteri; 10, Spirigera oxycolpos; 11, Rhynchonella austriaca; 12, Rhynchonella fissicostata; 13, Rhynchonella cornigera (all these being brachiopods).

which gives its name to the beds, and, among others, *Pecten valoniensis*, a species of scallop. But perhaps the most remarkable of all the fossils which the Rhætic strata have yielded is *Microlestes antiquus* (literally, the "old little robber)," a marsupial allied to the banded ant-eater of Australia, which fossil in America (in the beds of North Carolina), is

of the series—namely, the Kössen, the Dachstein Limestone, and the Dachstein Dolomite (Fig. 97)—are the equivalents of the Penarth beds. (Vol. I., p. 255, Fig. 124.)

They are arranged in regular series, and are distinguished by a number of fossils, many of which are engraved in Fig. 40. All of these fossils show unequivocally that the Alpine

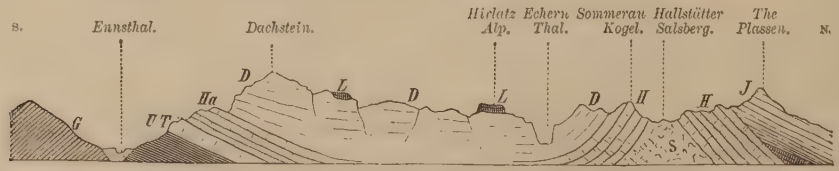


Fig. 97.—SECTION OF THE DACHSTEINGEBIRGES SANDSTONE, SHOWING THE ALPINE TRIAS, ETC.

G, Grauwacke; U T, Lower Trias (Werfen, rock-salt, Virgloria limestone); Ha, Upper Trias; H, Hallstadt (Hallstätter) limestone; D, Dachstein limestone; L, Lias; J, Upper Jurassic; S, Salt.

represented by the *Dromatherium*. This, it may be noted, is the first actual occurrence of mammals on the earth, though suspicions of their existence were not wanting towards the close of the Permian. In the Austrian Alps Trias was of marine origin, and had been deposited in an open sea not befouled by muddy sediment or sand, few traces of which appear among these enormous masses of limestone. The dolomites which enter so largely

into the composition of the Dolomite Mountains might have been coral-reefs.* In any case, the Alpine Trias, like the Rhætic generally, is a transition formation, though, unlike the latter, it shows not so much a blending of Triassic and Jurassic fossils as of true Palæozoic forms, with others which are unquestionably Mesozoic, thus pointing to the probability of these strata having originated under conditions different from those which obtained when the Trias generally of Germany was deposited. Indeed, though the Alpine Trias presents everywhere the same palæontological and other characteristics, the overlying beds offer data suggesting that very different physical conditions prevailed in adjacent areas during the period they were accumulating.

This period seems to have been one of great volcanic activity, and in Tyrol and other regions, signs are abundant of the Triassic age having been succeeded by frequent eruptions of melaphyre, gabbro, and other igneous materials. It is, therefore, quite possible that this classification of the Trias (of which only the briefest outline has been given) may be merely provisional, to be greatly altered when our knowledge of other regions becomes more extensive.

The annexed table may, however, be regarded as an approximately accurate classification of the Alpine Trias and the Rhætic beds in the different areas. It is placed by itself rather than risk confusion by endeavouring to arrange each group under the heads already given. In a synoptical form it embodies the conclusions arrived at from the long-continued researches of v. Hauer, Gümbel, Lipold, Peters, Stur, Pichler, Suess, v. Richthofen,

	Northern Limestone Alps.	Southern Limestone Alps.	Equivalents in the German Trias.
Lower Trias.	Werfen Sandstone. Guttenstein Limestone.	Seisser Beds. Campil „	Bunter Sandstein.
First Series of Limestones.	Virgloria Limestone. (Reiflinger-Kalk.)	Recoaro-Limestone.	Lower Muschelkalk. Wellenkalk.
Upper Trias.	Zlambach Beds. Partnach „	Wengen Beds. St. Cassian Beds.	Anhydrite, Gypsum, and Rock-Salt of the Muschelkalk.
Second Series of Limestones.	Hallstätter Limestone. Wetterstein „	Raibl Limestone. Schlern Dolomite. Esino Limestone.	Upper Muschelkalk.
	Cardita Beds. Lunz „	Raibl Fish Beds. Gorno and Dossena Beds.	Lettenkohle and Muschelkalk Bone Beds.
Rhætic Beds.	Upper Dolomite. Dachstein Limestone.	Dolomia media and Dolomia superiore of the Italian Geologists.	Keuper.
Third Series of Limestones.	Kössen Beds.	Avicula contorta Beds.	Avicula contorta Beds and Keuper Bone Beds.

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* Mojsisovics: "Dolomitriffe Südtirols und Venetiens" (1878); Stoppani: "Géologie et Paléontologie des Couches à Avicula contorta en Lombardie" (1860-65); Dittmar: "Die Contorta-Zone" (1864); etc., etc.

v. Mojsisovics, and others, and, for the present, may be accepted as a clue to this difficult series of beds which in the northern area attain a thickness of 6,000 feet.

Even now it is puzzling to assign the American Trias to any member of the ordinary threefold division, and similar doubts face us when we try to collate the strata of this system in other extra-European regions. The American beds which extend across the Rocky Mountains, do not observe the triple arrangement so marked in Germany. In Asia — Siberia, Kashmir, Tibet, the Salt Range, and Beloochistan—their classification is still more difficult. In Australia rocks usually termed Trias are the sandstones which form many of the cliffs along the shore of Port Jackson (Sydney Harbour), while the New Zealand beds seem to belong to the Upper Trias, or Rhætic, though in some of them Permian and even Jurassic fossils are found.

Life of the Period.—The Triassic flora was composed largely of ferns, herbaceous and of the tree-form, horsetails, conifers, and cycads; but though some of the old Carboniferous and Permian genera, such as *Pecopteris* and *Cyclopteris*, survived, the majority of them are new. Calamites are not quite extinct, but for the first time a horsetail of the common genus *Equisetum* appears (Fig. 95, 2), and has not ceased to exist at the present day in the form of between twenty and thirty species. *Voltzia* (Fig. 95, 1) was a conifer of a character akin to the cypress, and cycads were so abundant that the Triassic and the periods which succeeded it have been called "The Age of Cycads." *Zamites*, *Pterozamites*, and particularly *Pterophyllum*, were the most frequent genera. Their general appearance may be gathered from the engraving of a modern, or, as the geologist says, "recent," species (Fig. 99), though many of them, like *Zamia spiralis* of Australia, are

Fig. 98.—IDEAL LANDSCAPE OF THE KEUPER.

lowly forms without the lofty stem of the species figured. All of them are inhabitants of warm countries, so that some idea of the Triassic climate may be presaged from the occurrence of these plants. It may be added that these true cycads which now for the first time make their appearance with certainty, continue in abundance through the entire Mesozoic epoch, but, unless an exception be made in favour of a single doubtful species, vanish in the Tertiary Age.

Some of the animals have already been enumerated and figured. Most of these fossils have been derived from the Muschelkalk (Fig. 95), the Rhætic (Fig. 96), and the Alpine Trias (Fig. 40), the red beds being rather barren of life, as red beds not unfrequently are. We miss the great Palæozoic family of the Productidæ among the brachiopods, and though Orthoceras and Goniatites are still of the ancient world, Ceratites (Fig. 95, 9) and other Ammonites commingle with them in the Alpine Trias. Belemnites—the internal bone or shell of a naked squid or cuttlefish of the dibranchiate family, the "thunderbolts" of the rustics—now appear for the first time. Several new forms of fishes are found. *Saurichthys* (Fig. 96, 4), for example, and the modern mud-fishes (*Dipnoi*) are represented by several species of *Ceratodus*, which, like their living types the "barramunda," from the rivers of Queensland, were no doubt vegetable feeders. In the fact that these *Dipnoi* possess both gills and lungs, in addition to other corresponding points of structure, they are a distinct transition group between Fishes and Batrachia. Again, in the Keuper at Bromsgrove in Worcestershire, the remarkable *Dipteronotus cyphus*, the first fish with an equally-lobed tail, occurs. Labyrinthodonts still flourished, their footprints being found in many sandstones (Fig. 31), while bones (Fig. 95) are often met with. One of these, the *Mastodonsaurus giganteus* (the *Labyrinthodon jägeri* of Owen), from the "Alaunschiefer" of the Saildorf Lettenkohle (p. 137), had a skull three feet in length, while *Capitosaurus robustus* (Fig. 95, 12) seems to have quite deserved its name. In the Trias also appears the first specimen of that remarkable extinct order of reptiles known as the Dinosaurs, which, in some respects, are intermediate between cursorial birds, like the ostriches and cassowaries, and the true reptiles, while some anatomists will even go so far as to find affinities in their structure with that of the

Fig. 99.—LIVING CYCAD (*Cycas circinalis*) OF THE MALABAR COAST.*

pachydermatous mammals. Their skin, according to Huxley, was sometimes naked, though just as frequently covered with bony shields like that of the crocodiles. So abundant were some of these dinosaurs, that on a single slab of Triassic sandstone from near Stuttgart no less than twenty-four specimens of a species of *Aëtosaurus* were obtained. These were naturally small forms. But some of the "mailed bird-lizards" were of gigantic size, a single footprint sometimes

* From the seeds of this species a sort of sago is prepared.

measuring three feet in length. The great reptiles (Plesiosaurs), which played so prominent a part in the life of the coming Mesozoic ages, now begin to appear in the shape of *Nothosaurus*, etc. In South African strata, in addition to other species of different reptilian and batrachian families, we have the Theriodonts, with three sets of teeth like carnivorous mammals, and Anomadonts with no teeth, or only a pair like tusks (*Dicynodon*). Crocodiles also appear in the genera *Stagonolepis robertsoni*, which must have been sixteen or eighteen feet in length, and *Belodon*, which was not much less formidable. *Telerpeton elginense* is a lizard, but so peculiar that it stands by itself, while among other species from the same beds may be mentioned *Hyperodapedon gordoni*, which is allied to *Rhynchosaurus articeps*. It was a saurian reptile, about six feet long, and though originally discovered in the Elgin sandstone, has since been found in Triassic beds in India, a fact quite as curious, zoo-geographically, as that the *Dicynodon* of South Africa has also been detected in these Scottish beds. These reptiliferous sandstones of Morayshire have been attributed to the Old Red Sandstone, though the intervention of a conglomerate between them and the beds containing *Holoptychius*, in addition to the palæontological evidence, is not in favour of this view.

On Triassic slabs from the Connecticut River footprints, believed to be those of

Fig. 100.—BIRD-LIKE FOOTPRINTS ("ORNITHICHNITES") FROM TURNER'S FALLS ON THE CONNECTICUT RIVER, MASSACHUSETTS.*

different species of birds, have been detected. But hitherto no bones or other ornithic remains have been actually discovered. It is, therefore, beginning to be generally—though by no means universally—believed that these supposed bird footprints (Fig. 100) are really those of the Dinosaurs already described, the conclusion being that these reptiles walked mainly on their long kangaroo- or jerboa-like hind legs. Many of them were three-toed like birds, and, if walking in the manner indicated, their tracks might easily be mistaken for those of birds. At all events, no birds have as yet been found, though there is good reason for believing that birds had already appeared upon the earth. This is rendered probable from the fact that animals of a much higher organisation now present themselves. These consist of small mammals, *Microlestes antiquus* (Fig. 96, 6), of the Upper Trias of Europe, and *Dromatherium sylvestre*, which has been disinterred from rocks of nearly the same age in North Carolina. Both seem to have been allied to the banded ant-eater of Australia, a marsupial which, like the opossums, wombats, and kangaroos, carries its young in a pouch. However, as only teeth of the *Microlestes* and a jaw of the *Dromatherium* have hitherto been brought to light, this is a point which is still problematical. The earliest intimation of the existence of the first-named species was the molar tooth unearthed in 1847 from the Würtemberg bone bed (Fig. 96, 6). Other teeth were subsequently discovered in the Rhætic series near Frome in Somersetshire, and at a still later date Mr. Boyd Dawkins described from the Keuper beds near Watchet, in the same county, the tooth of an animal which he termed *Hypsiprymnopsis*, which has subsequently been pronounced to be identical with *Microlestes*. It is also interesting to note that these, the first suck-giving animals which came upon the earth, were, though not the most lowly organised of their class, by no means so highly developed as the forms which succeeded them,† no evidence

* The blocks containing such footprints being saleable at prices ranging up to £200, the Turner's River and Portland Quarries are now worked largely with an eye to supplying the demand for these costly specimens.

† See, for further particulars regarding some of the Triassic fossils, Huxley (on the Dinosaurs), *Quarterly*

of any value justifying the belief that "placental" mammals did not appear until a later period.

Physical Features of the Triassic Age.—The alternations of sandstones with marls, gypsum, and rock-salt, point to the Triassic rocks having been deposited in isolated basins or salt lakes, to which, as the limestones prove, the open sea must, at intervals of long continuance, have gained admittance. This is even more marked in the areas characterised by the Alpine Trias, which are not only of great thickness, but throughout essentially marine. The immense deposits of rock-salt which, to a depth of 120 feet, characterise the Upper Trias of England and other countries, point clearly to the conclusions mentioned. These great lenticular masses seem to have been formed by evaporation from super-saturated salt lakes like those of Utah and of Central Asia. The deposits are usually of a reddish tinge, due to the presence of iron rust and other ferruginous impurities (Vol. I., pp. 70–71, 326, and Figs. 134, 135, 136). One of these salt basins must have extended from England (of which it occupied a considerable part) to the south of Scotland and the north-east of Ireland, and, most probably, across what is now the English Channel into France. But we do not find any fossils in the rock-salt, and the briny waters of this lake being unfavourable to life, few fossils, except the remains of the plants which fringed its shores, and the footprints of the animals which ran along the mud flats exposed to the hot sun, are found in it, unless, indeed, when the sea broke in and the limestones were formed. There must also, about this period, have been another isolated basin in the vicinity of Elgin, since there the fossils are considerably different from those of any other area, and, with the exception of the peculiar reptiles which are found in these beds, are singularly devoid of any notable remains of the life of the period. On the Continent, James Geikie infers, from the range of the German Trias, that another vast lake covered a considerable part of Western Europe, the Harz Mountains being a rocky island in this inland sheet of water. The presence of the Muschelkalk, which is lacking in England, points to a prolonged period of influx from the sea. This connection with the ocean was then closed, and the deposits of gypsum, salt, and marl, formed, as in England, while the marine fauna disappeared. By-and-by this lake, as happened with the more westerly one, got silted up;* the sea then gained a mastery over a portion, and the Rhætic deposits were laid down in the areas thus covered. In North America much the same conditions prevailed. But the Alpine Trias point conclusively to an open sea having covered the area occupied by them. They are nearly all pronouncedly marine, while the mixture of old-world with the newer forms of life now coming in shows that, while in most other parts of Europe the break between the Permian and Trias was final, in this quarter there was still a sort of transition period in progress. This age, Sir Andrew Ramsay is convinced, must have been of vast duration. Indeed, the great continental era, which began with the Old Red Sandstone and closed with the Red Marls of the Keuper, is, in his opinion, comparable, in point of geological time, to that occupied in the deposition of the whole of the Mesozoic series later than the Keuper, and of the whole of the Cainozoic or Tertiary formations, "and, indeed, to all the time that has elapsed since the beginning of the deposition of the Lias down to the present day."†

The presence of cycads points to the climate of the Triassic Age being mild, while the wide

Journ. Geol. Soc., Vol. XXVI., p. 32, and (on the Crocodilian remains of the Elgin Sandstone) *Memoirs of the Geological Survey*, Monograph III. (1877); Von Hauer: "Die Cephalopoden des Salzkammergutes" (1846); Mojsisovics: "Das gebirge um Hallstatt" (*Abhandlungen der k. k. geol. Reichstanstadt*, 1873–75); Rupert Jones: "Fossil Estheriæ" (*Palæontograph. Soc.*, 1862)—; Fontaine: "Early Mesozoic Flora of Virginia" (1886); etc.

* This theory of silting up is rendered difficult of acceptance by the fact that mud in the shape of shale is nearly absent. Bonney (*Geological Magazine*, Dec. 2, Vol. VII., p. 407, and Jukes-Browne's "Handbook," p. 289) favours the idea of mountain currents sweeping down detritus.

† *Proceedings of the Royal Society*, No. 152 (1874).

range which many of the reptiles and other species possessed renders it probable that it was more equable over wide areas than is that of the same regions at the present time. South African fossils have been found in the Elgin sandstones, and in the Alpine Trias there are species common to rocks of the same age in Northern Siberia and New Zealand, the Sierra Nevadas of Western America, and the Himalayan range on the northern frontier of Hindostan. The range is, indeed, greater, for some of the most distinctive forms are also found in Spitzbergen,* though in this Age, as in its predecessor, there are traces of ice-rafts, in the shape of scattered blocks, which had their home in lands far distant from the spots where they now lie in the Triassic conglomerates. The volcanic outbursts which are found in the Alpine Trias indicate occasional disturbances during the period. As a rule, however, the Triassic Age was a calm one. In England, indeed, contemporaneous lava is found solely in Devonshire, and there only in the Lower Sandstones of the Bunter; Knowle Hill is a knoll of compact porphyritic lava. It is, however, perhaps unnecessary to remind the reader that at the time when the Triassic Age was in progress the Alps did not exist as mountains, though, if we accept the estimates of MM. Cornet and Briart, the northern and central parts of France rose at that period into peaks from 16,000 feet to 20,000 feet above the Muschelkalk Sea.

Scenic and Economic Aspects.—This comparative absence of igneous rocks gave the Triassic country a tameness comparable to that of the Permian regions. Indeed, what has been said regarding the districts covered by the rocks of that age, applies very fittingly to those occupied by the ones under consideration. Broad level expanses—never, in England at least, rising to a greater height than 800 feet—are characteristic of the country underlaid by these soft sandstones and marls, though in Shropshire, Warwickshire, and South Devon, the peaceful, undulating country, covered with rich pasture, is not devoid of beauty. The Alpine Trias is, of course, different, for the vast forces which threw these mountains into their present condition began to act long after the strata which now cover their flanks were laid down on the flat bottom of the sea. When the Triassic rocks form sea-cliffs, the manner in which they weather often affords scenery of an unusually picturesque character, though grandeur is never attained by them.

Where the Triassic marls have decomposed, the soil is well fitted for producing rich pastures, and on this clayey land some of the finest dairy-farms of Cheshire are situated. The sandstones do not usually make a good soil, the result being light and unfertile (as in Warwickshire), and when the water is retained by the shales, large swamps, like some of those in South Lancashire, are common. However, the disintegrated sandstones mixed with marl often constitute a deep loam, such as forms the arable land in much of the centre and west of England; but when the Conglomerates—formed of water-worn pebbles borne from some unknown region, and of sand, often mixed with ferruginous matter—come to the surface, the land is extremely barren. Sherwood Forest and Trentham Park, part of Beaudesert, and the ridges east of the Severn near Bridgenorth, are tracts of this description, the fact of their sterility being, as Sir Andrew Ramsay aptly suggests, the very reason why they remain uncultivated wastes in the middle of a well-tilled country. As a rule, the same explanation is applicable to the English commons. They are unoccupied simply because, in the majority of instances, the surface was too poor to make it worth ploughing and enclosing, being either on the soil mentioned, or on Eocene or boulder clay, which requires deep draining before being worth much to the farmer. The same eminent geologist who has just been quoted, notes as a curious fact that the fruit-tree districts of Great Britain lie chiefly upon red rocks, sometimes of the Old and sometimes of the New Red (Triassic)

* Nordenskjöld: "Geology of Spitzbergen" (1867); Oberg, "Om Trias-försteningar från Spetsbergen" (*Kong. Svensk. Vet. Handling.* Bd. 14, No. 14, 1877).

series. Devonshire, Herefordshire, and Gloucestershire—counties covered with orchards, white in Spring and rosy in Autumn, and famous for their cider and perry—lie in great part on these formations. The Carse of Gowrie, lying between the Sidlaw Hills and the Firth of Tay, is an Old Red Sandstone tract, famous for its apples, though what is

Fig. 101.—IDEAL LANDSCAPE OF THE LIASSIC PERIOD.

the reason for this, agricultural chemistry has not as yet been able to inform us. The Trias yields limestones, gypsum, and sandstones of various qualities. The city of Sydney is, for example, built out of stone generally regarded as belonging to this period. The finest quarries in the State of New Jersey are in Triassic sandstone, and out of it much of New York, Brooklyn, Newark, and other towns are built. Pennsylvania has also important quarries of a brown massive Triassic sandstone, in great request for facing the houses of Philadelphia, Baltimore, and Washington, while the rocks of the same age in North Carolina yield fine compact red stone of superior building quality.* The beautiful Salzburg "Tropsmarmor" is a marble mainly composed of the coral known as Lithodendron, which is abundant in the Dachstein Limestone (Fig. 97). But by far the most important economic product of the Trias are the beds of rock-salt, and the brine springs, formed by the dissolution of the salt† by the infiltration of rain-water. These have been already described (Vol. I., pp. 70, 71). There is coal also in the Trias, but this Lettenkohle, though worked to some extent in Austria, is of very poor

* "Tenth Census of the United States," Vol. X., (Special Report on Building Stones); Hull: "Building Stones" (1877); etc.

† Curiously enough, though bromine and iodine are found in the brine springs of Cheshire, these substances (presumably derived from the ancient sea-water) have not been discovered in the rock-salt of the same district.

quality.* But in America most of the Virginia and North Carolina coal fields, which are of great extent and good quality, are usually assigned to this System, or to that immediately succeeding it. One of the Virginia seams, from thirty to forty feet thick, consisting of pure bituminous coal, yields on analysis the same constituents as that of Northumberland, though the coal of these two regions is composed of entirely different assemblages of plants.

CHAPTER IX.

The Mesozoic Rocks: The Jurassic System.

Range and general characteristics of the System—Classification into Lias and Lower, Middle, and Upper Oolite—Life of the Jurassic Age—Plants—Cycads, Conifers, etc.—Lower Forms of Life—Fishes—Reptiles so abundant that this is the "Age of Reptiles"—Description of some of the Principal Forms—Teleosaurus—Ichthyosaurus—Plesiosaurus—Pliosaurus—Campsognathus—Megalosaurus—Ceteosaurus—Brontosaurus—Atlantosaurus, etc.—Pterodactyls—Pterodactylus—Rhamphorhynchus—Dimorphodon—Reptilian Birds—Archæopteryx—Laopteryx—Mammals—Description of some of these—Physical Geography of the Period—Economic and Scenic Aspects of the System—The great Dividing Line across England—Soils of the Jurassic—Building Stones and Slating Materials—Solnhofen Lithographic Limestone—Bituminous Shales—Fuller's-earth—Grindstone Cave of Morocco—Coprolites—Alum—Coal—etc.

William Smith, "the father of English geology," applied the term Oolitic to the series of rocks which, at a later period, from their extensive development in the Jura Mountains on the north-west frontier of Switzerland received the name of Jurassic. Neither name is satisfactory, but this is an objection which applies almost equally to all geological designations of the kind, though possibly the later title is better than the earlier, since it would seem to intimate that all, or a majority of, the Jurassic rocks are oolitic or roe-like in structure (Vol. I., p. 55). In reality, though the ordinary classification, which we adopt, conveys this idea to the uninitiated, the bulk of the Jurassic strata are clays, sandstones, shales, marls, and limestones, which in no respect possess the characteristic texture which suggested to the old mineral surveyor the name he applied to the formation on which he was born, and in which, by his dying request, he was buried. The lowest member of the series overlies the uppermost of the Triassic with perfect conformity, but throughout the area covered by the Jurassic rocks there is a curious localisation of types. The Jura of France differs widely in lithological features from that of Germany, while the Alpine series is different from either, from that of England, or from that of north-western India, or of America, each of which has a general facies of its own. Yet, in spite of this diversity in lithological structure—so directly in contrast with the uniformity of all the previous systems examined by us—the fossils of the Jurassic rocks are well marked, so that, though no general characteristics derived from the texture of the beds composing the System can be given, their homotaxis over the wide region which they occupy is much less difficult. Their thickness is very considerable—the various beds, from the Lias to the Portland Oolite, presenting in England alone a depth of between 4,000 and 5,000 feet. In Great Britain (*see* Map) they are chiefly developed in England, in the counties of York, Lincoln, and Cambridge, from which a broad belt extends to

* Hull: "The Triassic and Permian Rocks of the Midland Counties of England" (*Memoirs of the Geological Survey*, 1869); Usher: *Quarterly Journal of the Geological Society*, Vol. XXXII., p. 392 (on the Devon and Somerset Trias); Miall: *Quarterly Journal of the Geological Society*, Vol. X., p. 369 (Labyrinthodontia); Stoppani: "Paléontologie Lombarde" (1858); etc.

the Bristol Channel, and the shores of the English Channel, between Durlestone Head and Lyme Regis. In Ireland a few patches appear in Antrim; and in Scotland they are developed near Brora and Dunrobin in Sutherlandshire (with the accompaniment of coal); and in the Inner Hebrides—Mull, Skye, and Raasay—and in some parts of the west coast, where they have been preserved from denudation by enormous overflows of lava.*

Classification of the Jurassic Beds.—The usual system is to divide the series into four divisions, the lowest of which is the Lias, and the upper the Oolites. This plan is perhaps a little clumsy, though, from a scientific point of view, it is no more objectionable than the others which have been proposed in its place. Moreover, as being very widely adopted, it is better to adhere to it in the brief account which we shall give of the component members of the Jurassic formations.

(1) *Lias.*—This consists essentially of a series of bluish or greyish laminated clays, alternating with thin bands of blue or grey limestone, or as at Cleveland, where ironstones occur with beds of an arenaceous character, or actually, as in the top of the series, with considerable layers of sandstone. Hence the banded appearance of this formation when seen in section, and the Somersetshire quarrymen's name of "Lias" (the local pronunciation of "layers"), which William Smith applied to it. The formation is again subdivided into a Lower, a Middle, and an Upper Lias, though these sections lie one upon the other without any kind of break, except possibly one of a lithological character between the Marlstone and Upper Lias clay. There is therefore no ground for believing that there was any pause between the successive deposits so named. Each of them has, however, certain characteristic species, though it may be added there are several fossils common to the entire formation. In the Lower Lias we find numbers of the *Ichthyosaurus* and the *Plesiosaurus* (Figs. 102, 106, 115), huge reptiles, of which the first hint was afforded by the Rhætic beds. In the Middle Lias these reptiles are rarer, but in the Upper section they muster in force. Ammonites are also abundant, and of so many species, that there are zones or particular beds of the Lias distinguished by the presence of certain forms. In France, where the Jurassic beds surround the Cretaceous formation of the Paris Basin and the Crystalline rocks of the Central Plateau, the Lower Lias is represented by the Calcaire Sinémurien, the Calcaire de Valognes, the Grès de Lincksfield, and in Luxembourg and the neighbouring country by the Grès du Luxembourg. The most typical development is exposed at Semur in Côte d'Or (hence the name "Sinémurien"), where it consists of nodular limestone divisible into three zones, marked respectively by *Ammonites rotiformis*, *A. bucklandi*, and *A. stellaris*. In Germany, the Gryphitenkalk and the Lower Black Jura are its representatives.

The Middle Lias or Marlstone is in France represented by the Terrain liassien, the Marnes (marls) de Balingen. In Germany the numismalen mergel (marl), the amaltheenthon (clay), and the Middle Black Jura are usually regarded as its equivalents.

Finally, the Upper Lias is in France the Terrain toarcien and the schistes de Boll. The Posidonomya beds, the Jurensis mergel, the Opalinus thon, and the Upper Black and Lower Brown Jura, are the German equivalents.

Jurassic rocks are found in America only here and there, and then to no great thickness, among the Colorado Rocky Mountains, the Black Hills of Dakota, the Wind River Mountains, the Wahsatch Range, and other parts of the extreme western section of the United States, and they have been recognised in widely-scattered spots in the Arctic regions. But what is their exact position in the system has still to be settled, but they seem to range, in the Polar Basin at least, from the Lias to the Middle Dogger (p. 141). Though not playing any important part in the system, the Jurassic strata of Colorado are remarkable for the extraordinary collection of reptiles — tortoises, pterodactyles, dinosaurs,

* Judd, *Quarterly Journal of the Geological Society*, Vol. XXXIV., p. 660.

crocodiles, etc., which Professor Marsh has disinterred from them, in addition to several small marsupial mammals. In like manner, the Russian Jurassic strata cannot well be correlated, though it is known that none of them belong to this division, those of the south and east of the empire belonging, for

Fig. 102.—IDEAL LANDSCAPE OF THE LOWER OOLITE PERIOD.

the most part, to the upper members of the series (Fig. 101).

(2) *The Lower* (Bath) *Oolite.* — This division has been divided into a number of well-marked groups: (*a*) The Inferior is composed of calcareous freestones. It is the Terrain Bajocien, the Calcaire Lædonien, the Calcaire à polypien, and the Marnes Vésuliennes, of France; in Germany, the Eisen-Rogenstein, the Discordien-mergel, and the Dogger, Middle, or Brown Jura. (*b*) The Fuller's-earth, a series of shales, marls, and the clay from which it takes its name. (*c*) The Great Oolite (or Bath Oolite, as it is sometimes called by way of distinction) is made up of calcareous oolitic sandstones, flags, and blue limestones tending to flagginess in the fossiliferous beds locally known as the Stonesfield slate. (*d*) The Forest Marble and the Cornbrash are limestones, clays, and sands, either oolitic or simply shelly. In this group may be included the Kelloway Rock (Vol. I., p. 55) of Wilts and Yorkshire, which is entirely made up of shells, etc. In France these two divisions, in addition to the Fuller's-earth and the Great Oolite, may be considered to be represented by the Terrain Bathonien, the Calcaire de Caen et Ranville, the Terrain Collovien, Oxfordien Inférieur, and portions of the Brown Jura.

In Yorkshire the Lower Oolites contain workable seams of coal, and the Brora coal-field in Sutherlandshire has been regarded as of the same age, though it is now settled that the reefs below Dunrobin Castle, in the same

county, must be attributed to the Lower Jurassic period.

The term "oolitic" has been already explained as being derived from two words* signifying egg- or roe-rock, from the appearance of the principal freestone which enters into its composition. Indeed, the Gloucestershire quarrymen have long recognised this similarity by giving the name of "roestone" to the finer varieties, and "pea-grit" to another rock in which the concretions are of larger size. Though these oolites are mainly members of the series to which they give their name, they are not confined to it, for a Liassic marl near Larne in Co. Antrim (Ireland), various Carboniferous, Permian, and other limestones, and certain Tertiary strata in Italy, have been noted as exhibiting the oolitic structure. Indeed, if, as has been stated to be the case, an oolitic limestone is at this moment being formed in certain of the Mexican lakes by the eggs of a fly forming the nuclei around which the calcareous matter accumulates, and on the shores of the Great Salt Lake of Utah, oolites may have formed in almost any age of the earth, though the conditions favouring them seem to have obtained more completely in the Jurassic than in any prior or subsequent age.

Fig. 103.—IDEAL LANDSCAPE OF THE MIDDLE OOLITE PERIOD.

Some of the marine beds of Cutch, which run from the Inferior Oolite to the top of the series—a thickness in all of 6,300 feet—belong to this division, while those of New Zealand and South Africa may be provisionally regarded as assignable to this or to nearly akin formations, though the fossils found in the Jurassic beds of the Antipodes do not as yet permit a confident opinion to be formed on that point. The beds known in Germany as Dogger or Brown Jura may be regarded as equivalent to the Lower Oolites of England,

* Greek, *oon*, an egg; and *lithos*, stone.

though in Yorkshire the sandy, often oolitic, ironstone overlying the lias is looked upon as its exact representative (Fig. 101).

(3) *The Middle* (Oxford) *Oolite* comprises a dark-blue, tenacious clay, with some calcareous sandstones; and still higher up, a mass of limestones so filled with corals that they seem almost entirely composed of them, though others are oolitic, or even fine-grained, the oolite being frequently overlaid by calcareous sandstones and grits, and rest on beds in strata of a similar character. The first series are known as (*e*) the Oxford clay, which, to the maximum thickness of about 700 feet, is widely distributed in England; while the other (*f*), which averages from 150 to 250 feet, has been termed, for the reason already given, the Coral Rag.

In Germany (Vol. I., p. 255, Fig. 124), where the Jurassic rocks cover much of North-west Germany — Franconia, Swabia, and Upper Silesia — in addition to several detached areas, the Middle and part of the Upper Oolites of England are represented by the Malm or White Jura, though the Oxford clay comprises in addition part of the Brown Jura, the Ornaten thon, the Impressa kalke, and the Spongiten layer. It is also probable that the Solnhofen limestone (Fig. 118) should be assigned to the Coral Rag rather than to the Kimmeridge Clay of the Upper Oolites. In France, the Oxford Clay and the Coral Rag are represented by a series of beds, to which the names of (1) Terrain Oxfordien, Argovien, and à Chailles, and (2) Terrain Corallien, Schistes de Nattheim, and Calcaire à nérinées, have been given (Fig. 103).

(4) *Upper* (Portland) *Oolites.*—These consist of three groups. The one (*g*) immediately above the Coral Rag is the Kimmeridge Clay, which generally consists of a series of laminated or shaly slate sometimes bituminous, intercalated with ferruginous oolite, or calcareous grit, to 500 or 650 feet in the British Islands. Its popular name is derived from Kimmeridge, in Dorsetshire, a county through which it extends, into Wilts, Lincolnshire, and Yorkshire. The best section in England is at Ringstead Bay, in Dorsetshire, where its division into lower, middle, and upper clays, each marked by a different group of fossils, can be easily seen through the 650 feet to which the cutting extends. However, at Speeton Cliff and Filey Bay, in Yorkshire, the holiday-maker may see the Kimmeridge Clay in almost equal perfection. The French equivalents of the Kimmeridge Clay is the Terrain Kiméridgien (the argilles noirs de Honfleur, the Marnes du Bauné, and the Calcaires à Astartes), and, Mr. Etheridge is of opinion, a portion of the Terrain Portlandien of the Swiss Jura. Part of it is included in the German Malm.

The next division (*h*) is the Portland Beds, sandstones and limestones found in various parts of England and the Continent, which in the Isle of Portland reach a thickness of 100 feet. In France these beds take the same name (Terrain Portlandien). They are represented by the Calcaire à tortues de Soleure, and, like some of the preceding, are comprised in the Malm of the German geologists, the Eimbeckhaüser Plattenkalke being its nearest equivalent. Finally, topping the entire Oolitic series are (*i*) the Purbeck Beds—a remarkable group of strata—alternately fresh-water, brackish, and marine, though for the most part fresh-water, in this respect differing from all other of the series. They point to the land at the close of the Jurassic Period having been raised above the sea level, in what is now the South and South-west of Europe, since in the 150 feet of beds which constitute the English Purbeck is found (in the limestone of the Isle of Portland) a layer of earth—the well-known "Dirt bed"—containing the silicified stumps and trunks of several conifers and cycads of an average diameter of one foot. These stumps stand erect in the sloping bed, and seem to have become fossilised in the ground in which they grew. The brackish water strata overlie the "Dirt bed," and these again are capped by fresh-water, and occasionally marine layers, the fresh-water strata being celebrated for the mammals, reptiles, and insects which have been disinterred from one of their thin marl bands. The Jurassic Period was

essentially the "Age of Reptiles," but it would seem that their high noon was especially towards the close of the Period, or at the beginning of the Age which followed. In France the "Purbeckien" appear to be represented by the Marnes à gryphées virgules of Argonne, though it is by no means settled what are the exact equivalents of this series over the Channel, the "Tithonian beds" of Oppel being more of a transition character than any in England, unless indeed the Wealden is comparable with them. In Germany, the Serpulit limestone and the Münder Mergel form a transition between the Purbeck and Portland (Fig. 104).*

Life of the Jurassic Period.—Plants and animals seem not only to have been plentiful during this Age of the earth, but owing to the character of the deposits accumulated during its continuance, and the absence of that superabundance of brine in the ocean and inland seas which formed so marked a feature of the two preceding Periods, the conditions for their preservation appear to have been more favourable than at any former stage of the world's history. The changes affecting the life of this Period seem to have acted more rapidly than at an earlier date, for not only are the species many and varied, but each bed is distinguished by several peculiar to it, this fact standing out in sharp contrast with what prevailed during the Trias (p. 132). Vegetation was still abundant, though the grade of development did not advance beyond the gymnosperms (the cycads and the conifers). These were, however, extremely abundant, while horsetails of the most gigantic description, and ferns, most of them of new species, mingled with the firs, arbor-vitæ-like trees (*Thuyites*), and Araucarias as far north as Spitzbergen and East Greenland, where during the Jurassic Age there must have been an almost tropical jungle of the vegetation named. Most of the Jurassic cycads, like those of the Mesozoic epoch generally (and between thirty and forty have been described from the British strata alone), seem to have had short stems, like the Zamias of modern periods, though some, like that figured on p. 133, must have been lofty, like palms. Those of the Purbeck "Dirt bed" are stumpy forms belonging to the genus *Cycadeioidea*† of Buckland, in whose days, as in ours, their peculiar shape suggested to the quarrymen that they were "fossil birds' nests." Arads were, however, not unknown, and several fruits have been described which probably belonged to the living order of *Pandaneæ* or screw pines.

Interesting as was the flora of the Jurassic Period, it yields in importance to the fauna. Indeed, no formation in Britain presents so rich an assemblage of animal remains as the Jurassic beds, no less than 4,500 species, speaking approximately, having been described from them. All of the lower forms of life swarmed —foraminifera, sponges, crinoids (fixed and free) starfishes, sea urchins—and so numerous were the corals, most of which belong to the reef-building family of star corals, that, as we have seen, many rocks, like the Coral Rag, are all but composed of them. New mollusca made their appearance, and though brachiopods are by no means the all-abounding family which they were in Palæozoic times, many of the old genera, and several with which we have not hitherto met, make their appearance. The modern genera, *Rhynchonella* and *Terebratula*, are among these, but *Leptæna* and *Spirifera* we meet with for the last time. Other shellfish are also well represented, some of them—*Lima*, *Cardium*, *Lucina*, and *Pecten*—of genera yet existing in our seas. Cephalopods are still characteristic molluscs, though the familiar *Orthoceras* and *Goniatites* have for ever vanished, to give place to *Nautilus* in several forms; and so many Ammonites existed

* This synopsis has been drawn up mainly from the data contained in De Lapparent's "Traité de Géologie" (1885); D'Archiac's "Paléontologie de la France" (1868), and its continuation under the title of "Paléontologie Française;" Credner's "Ober. Jura in N. W. Deutschland" (1883); Oppel's "Juraformation Englands, Frankreichs, und Deutschlands" (1856); Quenstedt's "Der Jura" (1858); Braun's "Unter. Mittl. und Ober. Jura" (1869—74); Benecke's "Trias und Jura in den Südalpen" (1866); Renevier: "Tableau des Terrains Sédimentaires" (1884); Etheridge's edition of Phillips' "Manual" (1885); etc. etc

† The *Mantellia nidiformis*, etc., of more recent writers.

that over 300 species have been described, particular beds of the Lias being characterised by particular species of these cephalopods which, from their shells being curled like the horn on the statues of Jupiter Ammon, have received their generic and family name (Fig. 105, 1, 3, 6, 8, 11, 12, 14, 15, 24; and Fig. 116). They are the drawings. *Belemnites*, the "Donnerkeile" of the German peasants, is the most common genus of these cuttlefishes, which evidently, from the enormous quantity of their remains, thickened the waters of the Jurassic seas (Fig. 105, 1, 16; and Fig. 117). True crabs, besides many other crustaceans, are frequent,

Fig. 104.—IDEAL LANDSCAPE OF THE UPPER OOLITE PERIOD.

snake stones, or the Whitby snakes of unscientific observers, and, though all bearing a general resemblance, are zoologically so varied that they have been divided into fifteen groups, according to certain peculiarities in the form of their beautiful sculptured shells. The shell-less forms are also numerous, their remains consisting of the parrot-like beaks, the internal bone, usually composed of carbonate of lime, and the ink-bags, in which the "ink" is so well preserved in a rocky form, that, when ground down, it can be used for sepia while among other articulata, worms of different species have, like the limy-tubed *Serpulæ*, which cement themselves to stones and dead shells, left their impression on the retentive strata of this Period. The most characteristic of these fossils are engraved in Fig. 105. On the whole, this aquatic fauna shows a tendency to the modern type more marked than any we have as yet studied, for, in addition to the genera mentioned, the bivalves approximate to living forms. Oysters appear, so do limpets, and other modern genera

of univalves; and *Diceras* (Fig. 105, 26), a bivalve which gives a character to certain Oolitic limestones, is near akin to the gigantic *Chama* of southern seas.

Insects are now quite numerous, some of the thin bands of the Swiss* and English Lias being full of them. They consist of cockroaches and grasshoppers, beetles of modern families, spiders, and many neuropterous insects, the Jurassic uplands by the streams which poured the sediment of the mountains into the ancient Liassic sea, a state of matters which is quite common at the present day.† As many of the English beetles, and fully one half of the hundred species described by Heer and others from the Swiss Lias, are wood-eating forms, we are justified in inferring, even if no plants had been found, that, in

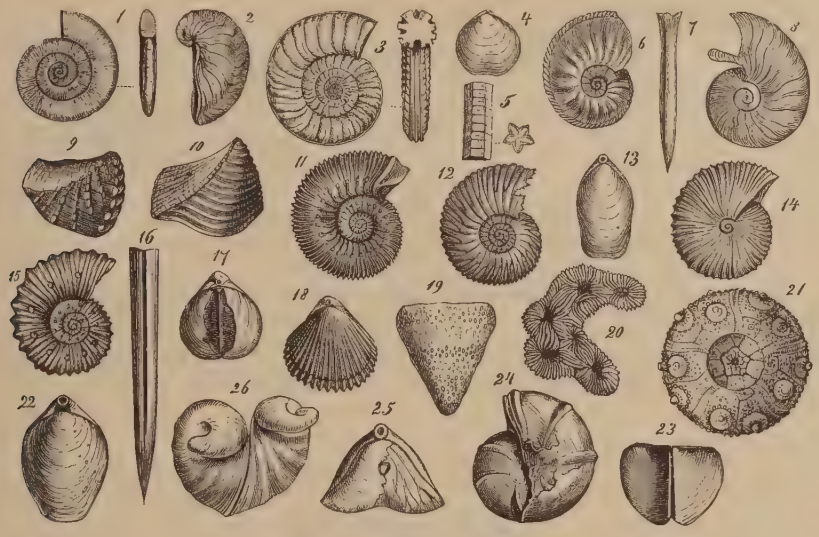


Fig. 105.—JURASSIC FOSSILS.

(LIAS): 1, Ammonites (Aegoceras) planorbis (psilonotus); 2, Gryphæa arcuata; 3, Ammonites (Arietites) bucklandi; 4, Terebratula (Waldheimia) numismalis; 5, Pentacrinus basaltiformis; 6, Ammonites (Amaltheus) margaritatus (amaltheus); 7, Belemnites paxillosus. (OOLITES): 8, Ammonites (Harpoceras) opalinus; 9, Trigonia navis; 10, Trigonia costata; 11, Ammonites (Stephanoceras) humphriesianus; 12, Ammonites (Cosmoceras) parkinsoni (planulatus); 13, Terebratula lagenalis; 14, Ammonites (Stephanoceras) macrocephalus; 15, Ammonites (Cosmoceras) ornatus; 16, Belemnites canaliculatus; 17, Terebratula impressa; 18, Rhynchonella lacunosa; 19, Spongites reticulatus; 20, Astrea confluens; 21, Cidarites coronatus; 22, Terebratula insignis; 23, Aptychus latus (lævis); 24, Ammonites (Phylloceras) tatricus; 25, Terebratula diphya; 26, Diceras arietina. The species from 8 to 16, inclusive, are especially characteristic of the Dogger Beds of Germany; those from 17 to 26 are chiefly from the Malm.

like dragon-flies, one of which, preserved in a wonderfully perfect condition in the Solnhofen limestone, is figured on p. 30. In the Lias a remarkable assemblage of insects—all closely allied to existing species, and therefore likely to be inhabitants of more temperate climates than the associated fossils would lead us to believe that of the Age—has been found. Indeed, the small size of most of these indicate a cool habitat, so that it has been suggested that they were washed down from addition to the insects which fluttered among the flowers of the Period, and skimmed over its sunlit pools, there was ample herbage for them to devour, and tree-trunks, many of them crumbled into dust, for these beetles to burrow among.

Butterflies for the first time appear. This species is *Palæontina oolitica*, from the Stonesfield slate, and finds its nearest allies in certain modern species in these times found

* At Schambelen in the Canton Aargau.

† Ramsay: *Memoirs of the Geological Survey*, Vol. I., p. 325.

only in tropical America. Moths also now for the first time arrived, with their relatives the butterflies. One of these, the *sphinx snelleri*, from the Solnhofen limestone, is thought by imagination are the numerous reptiles, and the extraordinary character of some of them. Reptiles we have met with in former Ages; but it is in this Period that this class reached

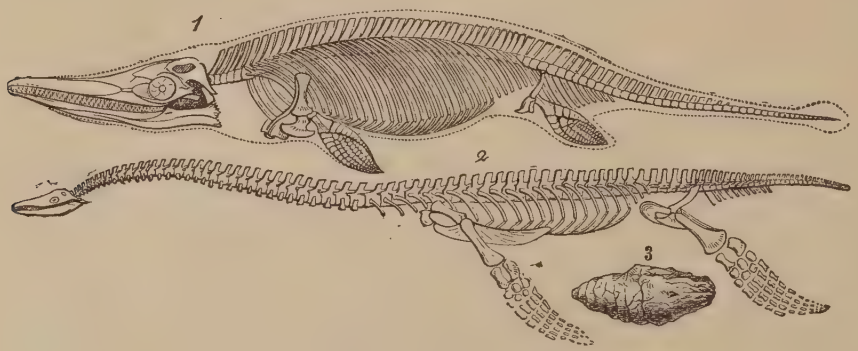


Fig. 106.—SAURIANS OF THE JURASSIC PERIOD.

1, Ichthyosaurus communis; 2, Plesiosaurus dolichodeirus; 3, Coprolite of Ichthyosaurus.

the discoverer to have been, unlike modern moths, provided with a sting.

Fishes were also plentiful. More than 220 species, most of them from the Lias, have its fullest development. There were no true snakes, but numbers of turtles and tortoises, crocodiles, and lizards. One of the crocodiles was the *Teleosaurus*, of the York-

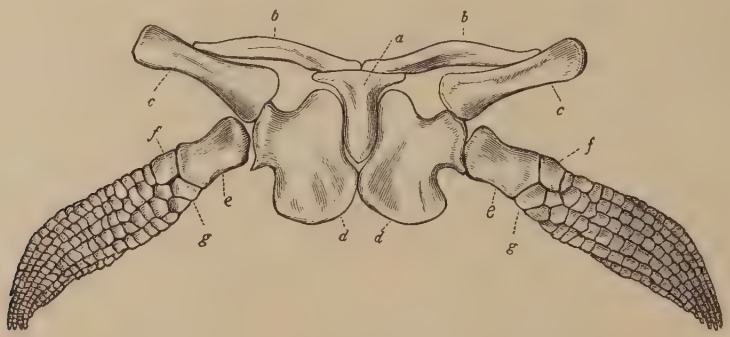


Fig. 107.—THE SHOULDER GIRDLE AND FORE LIMBS OF THE ICHTHYOSAURUS VIEWED IN FRONT.

a, *b*, *c*, *d*, Bones of the shoulder girdle; *e*, Bone of the upper arm; *f* and *g*, Bones of the forearm, followed by the bones of the wrist and fingers.

been described, and many of the ganoids have homocercal tails, thus showing a marked approximation to the higher type of their class. Cestracions were still plentiful, and true sharks were present in the Jurassic seas, along with rays and other placoid forms.

But of all the fossil remains of the Jurassic Age, those which most vividly impress the shire Lias and Stonesfield Slate, a huge brute eighteen feet long, and thought to have been addicted in search of its prey to venture more freely to sea than the alligator of the New World rivers, the gavial of the Ganges, or its well-known relative of the Nile. Still more characteristic of the age were the reptiles known as the *Ichthyosaurus* and *Plesiosaurus*

(Figs. 106, 115). The first belonged to an order of which no modern representatives exist, though numerous fossil forms are known, and the remains of some of these are particularly abundant in the Trias. They were fish-shaped so far as the body was concerned, but, unlike any fish, were furnished with two pairs of powerful swimming paddles. In other respects, such as having a vertical tail-fin, they might possibly have approached in external appearance to the fishes, though in every other respect they were true fish-devouring reptiles. The eyes of this *Ichthyosaurus* — literally the "fish lizard"* — were very large, and the eye-ball was surrounded with a ring of bony plates, which have in most cases been perfectly preserved. The jaws were of wide gape, and furnished with teeth, which had no distinct sockets, but were placed in a common groove.

There is no reason to doubt from their surroundings that the Ichthyosauri were marine reptiles, which swam the Jurassic seas in search of fishes. Indeed, in their biconcave vertebræ, or "joints" of the back bone, these huge reptiles, some of which must have been between twenty and thirty feet in length, approached fishes. Yet their structure points unmistakably to their having been true air breathers. They thus combined many of the characteristics of the fishes, the whales, and the class to which they are properly assignable. Their "flippers" (Fig. 108) lead to the inference that they kept well out to sea, though the strong bony arch (Fig. 107) supporting the fore limbs justifies the conclusion that at times they crept up and sunned themselves on the muddy Liassic shores. When diving or contending with the waves, the bony shield of their eye-balls would protect them from injury or pressure, and we may equally infer that a pupil so large, and an orbit so wide, allowed of this reptile's vision being exceedingly keen. As for their other traits, even did not the huge mouth, the powerful-pointed teeth, and the long jaws, tell their own tale, the scales and bones of the ganoid fishes, found in their coprolites, or petrified droppings (Fig. 106, 3), would render this conclusion as to their carnivorous habits quite inevitable.†

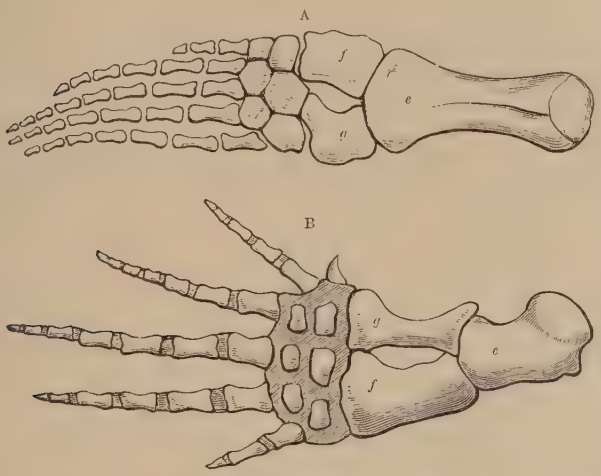


Fig. 108.—PADDLE OF PLESIOSAURUS AND DOLPHIN COMPARED.

A, Paddle of Plesiosaurus; B, Bones of the "flipper" of Dolphin; *e*, Bone of the upper arm; *f*, *g*, Bones of the forearm.

In addition to "this monstrous eft of old, the lord and master of" the sea, the *Plesiosaurus* (Figs. 105, 114) was the Jurassic representative of another order of extinct reptiles. Unlike the *Ichthyosaurus*, which had no marked division between the head and trunk, the Plesiosaurus had a long neck. Its paddles were also much larger in proportion to its body, its head was small, and its teeth inserted into regular sockets, so that, as its name signifies,‡ it was nearer to the saurians than the genus with which it associated. Like the Ichthyosaurus, it was clearly marine, though, in common with the turtles, it might have occasionally frequented the shore; and, as its respiratory organs are so constructed that it

* Greek, *ichthys*, fish; *sauros*, lizard.

† Nicholson: "Palæontology," p. 370; Whidborne: *Quarterly Journal of the Geological Society*, 1881, p. 480.

‡ Greek, *plesios*, near to; and *sauros*, lizard.

must have often required to breathe, there is no likelihood of this snake-like lizard having kept for prolonged periods in deep water, as tured the reptilian victims of the all-powerful "Vril" as doing. Some of the species of this genus which survived from the Lias to the

Fig. 109.—FLYING REPTILES OF THE JURASSIC EPOCH.

1, *Rhamphorhynchus gemmingi*, Zitt. (restored) from Winterberg, near Eichstädt in Bavaria, nearly akin to, if not identical with, *R. phyllurus*, Marsh. ; 2, Right fore-extremity of *Pterodactylus* ; 3, Flying apparatus of bat for the purpose of comparison ; *cl*, Clavicle or collar-bone ; *sc*, Scapula or shoulder-blade ; *h*, Upper arm or humerus ; *u*, Ulna ; *r*, Radius (bones of the forearm) ; *c*, Carpus or wrist ; mc_2-mc_4 Metacarpus or upper hand bones (mc_1, thumb of the pterodactyle) ; d_1-d_5, The phalanges or fingers (d_1, the thumb of the bat).

the "sea-serpent" is supposed to do, or as Bulwer Lytton, in his "Coming Race," has pic- Cretaceous were fully twenty feet in length *Pliosaurus*, though akin to the *Plesiosaurus*,

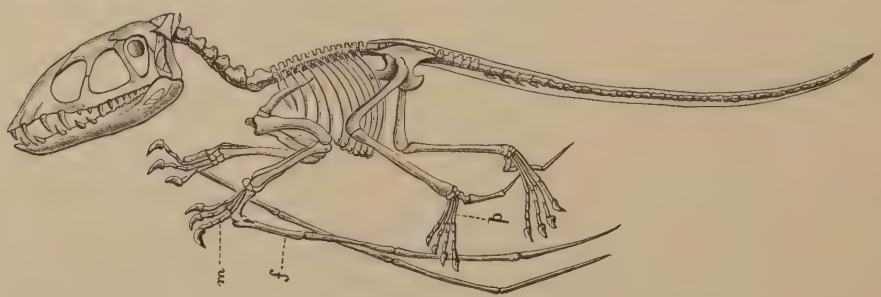


Fig. 110.—SKELETON OF PTERODACTYLE (DIMORPHODON MACRONYX), GREATLY REDUCED IN SIZE AND RESTORED. (*After Owen.*)

m, Hand or fore-foot ; *f*, The greatly elongated finger carrying the flying membrane ; *p*, Hind-foot.

was more saurian still,* for its head was larger and its neck shorter than that genus.

The *Pterodactyles*,† or flying lizards (Figs. 109, 110), were animals of this and the next Age, which, if not so large as those mentioned, were in many respects even more peculiar. Like the bats among mammals, they were capable, not only of supporting a brief aërial spring, or, like the so-called flying lizards of India and the Indian Archipelago and the flying "foxes" or phalangers of Australia, of merely breaking their fall or jumping from one branch to another, but of imitating birds in their movements through the air. Their locomotive apparatus resembled the bat's (Fig. 111), though, unlike the bats, which have the fingers of the fore-paw prolonged to support a membrane, the Pterosaurs of the Jurassic Age had one finger of each fore-foot prolonged to a great length for the same purpose, and had, in addition, their bones hollow and air-filled like those of birds.‡ The oldest and best-known genera are *Pterodactylus*, *Rhamphorhynchus*, and *Dimorphodon*, the last specially distinguished from the others by its long front and short back teeth, and by the extreme length of its tail (Figs. 109, 110, 111). *Rhamphorhynchus*, of which several species are known, was an even more vulture-looking creature (Figs. 109, 112). Some of them have remarkably long tails, though all had powerful jaws, and were otherwise well fitted to prey on either land or water, or to dive into the sea depths. These Pterosaurs (or winged lizards) appear first in the Lias, but are most abundant in the lithographic limestones, which have yielded so extraordinary a collection of reptiles. The *Rhamphorhynchus* seems not to have had any teeth in the front portion of its jaws, which portions, it has been suggested, were sheathed in horn so as to constitute, in some species, a sort of beak (Fig. 112).§ The sclerotic coat of the eyeball was, as in the *Ichthyosaurus*, surrounded by a ring of bony plates, and, in various details of their structure, the Pterosaurs were allied to birds, though in other respects true reptiles.‖ Most of these winged lizards were comparatively small, though one from the Cretaceous Period might have had a

Fig. 111.—PTERODACTYLE (DIMORPHODON MACRONYX) RESTORED, THOUGH GREATLY REDUCED IN SIZE. (*After Owen.*)

* Greek, *pleion*, more; and *sauros*, lizard.

† Greek, *pteron*, wing; and *daktylos*, finger. *Pterosauria*, Greek, *pteron*, wing; and *sauros*, lizard.

‡ Marsh, *American Journal of Science*, April, 1882.

§ The name *Rhamphorhynchus* is from the Greek *rhamphos*, a bird's beak, and *rhynchus*, a snout.

‖ Professor Seeley has put them into a distinct class called *Ornithosauria*, which he regards as most nearly related to, and equal in rank with, the Class of birds. See also Newton in *Proceedings of the Royal Society*, March 22, 1888.

wing-expanse, from tip to tip, of more than twenty feet. The Dinosaurs, which began in a former age, now attained great development in size, species, and abundance.

Among the numerous genera, *Campsognathus*, also from the teeming Solnhofen limestone, has the bird-like characteristics of this reptilian order even more marked than usual.* But *Megalosaurus*, of the Lias and Stonesfield Slate; *Ceteosaurus*, of the Forest marble and Kimmeridge Clay; *Brontosaurus*, of the Jurassic beds of Colorado; *Stegosaurus* and *Atlantosaurus*, of the same formation—were infinitely more gigantic representatives of this gigantic order of reptiles, with long hind- and short fore-legs.

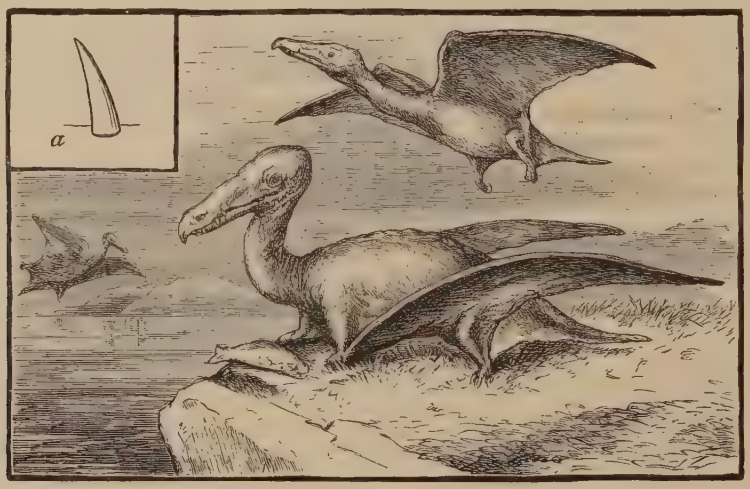


Fig. 112.—RHAMPHORHYNCHUS BUCKLANDI, GOLDF. (RESTORED).

a, Tooth, natural size.

Megalosaurus was a carnivorous animal with a head four or five feet in length, and powerful jaws armed with savage, sabre-shaped teeth, sharp and saw-like on their edges. Its length could not have been less than twenty-five feet, and its weight, when in life, fully must have reached a height of ten feet and a length of fifty feet. Its thigh bones measure over five feet in length and a foot in diameter, and altogether it must have been a formidable neighbour, whether in the danky jungles of cycads, ferns, and conifers, which it frequented when in search of food, or the waters to which, like the modern hippopotamus, it might have resorted. *Brontosaurus*, however, indicates that the Dinosaurs of this age were capable of even greater development than they attained in the old world. Though its head is small, its limbs were so massive that its footprints cover about a square yard in area, while from the tip of

* In Australia there is a living lizard (*Chlamydosaurus*) which runs on its hind legs and even perches on trees. This animal Dr. Henry Woodward suggests as possibly a distant relation, in habits at least, to these Dinosaurians or "fearfully great lizards," as the word signifies (Greek, *deinos*, monstrous; and *sauros*, lizard).

its nose to the end of its long tail—and the tail and neck made amends for the smallness of its head—this huge reptile is thought to have measured fifty feet and to have weighed more than twenty tons. Yet, large though it was, this animal appears, like the one just described, to have been a slow-moving, sluggish, rather dull-witted beast (for the brain was small), living on vegetable matter rather than on the animal life around it. *Stegosaurus* had its skin covered with many bony plates, some of them three feet in diameter, and altogether seems to have been an uncouth member of an uncouth race. The *Atlantosaurus* was, however, the most elephantine of all these new world "monstrous lizards." It has been reckoned by the discoverer, though on data not generally regarded as sufficient, to have reached one hundred feet in length and to have stood thirty feet high — higher than the largest elephant; its upper hind-leg bones are eight feet long, the long vertebræ twenty inches, and the shoulder-blades five feet long, so that no reptile of any age, and no living or extinct quadruped, can be compared with this giant brute. These and a host of similar, though smaller, animals, described by Cope and Marsh from the rocks of Western America, appear to have been haunters of the water rather than of the land, a habit to which the cavernous structure of their bones lends aid; while, if, as Owen suggests, the osseous cavities were filled with cartilage, these Behemoths—these "chief of the ways of God"*—must have had skeletons combining in a remarkable degree lightness with strength.

But the Jurassic beds contain fossils of a character even more extraordinary than any yet described. Hitherto, we have not obtained any proofs that birds existed upon the earth—Triassic footprints (p. 134) usually attributed to them being not unlikely those of the Dinosaurs, whose bones are found scattered in the same Formation. It does not necessarily follow that birds were absent, though, for many reasons, the negative evidence quoted may be accepted as positive proofs of their absence. They might have been present, though the stratum containing their remains has yet to come to light. Any one who has observed Nature closely must have remarked how exceedingly rare it is to find the dead body of any wild animal. Millions die every year; yet, unless after a heavy storm, or a severe frost, the sharpest-eyed ranger of the woods and fields will seldom come upon a corpse. The wildlings seem to creep into holes when they feel their end approaching, or their bodies are devoured by other animals, or concealed by their kindred. In the first and last cases, their skeletons will, of course, be preserved in the earth's crust all the same, as if they had been buried in aquatic mud; but if they are eaten, then it is only in rare instances that we can identify the component portions of their bony structure. This may be the reason why some animals are never found except in the shape of a few teeth, and it may also explain the absence of birds from Formations in which they might presumably be found. Birds can more easily escape any terrestrial disturbance likely to overwhelm animals without such capabilities of fleeing from the mischief at hand; so that it is by no means a safe inference to consider the spot in which a bird's skeleton is found that in or about which its owner was in the habit of disporting itself. Moreover, in former ages, as in our ours, birds were no doubt migratory; indeed, there is reason to believe — as we shall learn by-and-by — that the routes at present taken by certain species in removing from and to their summer and winter quarters, were those adopted by them when the physical geography of the world was very different from what it is at present. We also know that when birds are drowned —and after a boisterous winter the Northern coasts are often strewed with the bodies of aquatic species—they invariably float on the surface, owing to their light skeletons and water-resisting plumage. Hence, when they

* In the *American Journal of Science* for 1879–1886, Professor Marsh has described these and numerous other Jurassic and Cretaceous Dinosaurs from Colorado and other of the Western States. *See* also Cope: "United States Geological Survey of the Territories," Vol. II. (1875).

reach the strand, their carcases are usually so macerated that their bones are scattered far and wide, or they fall a prey to the animals who prowl along the shore intent on picking up such flotsam and jetsam of the ocean. Other large animals, on the contrary, sink to the bottom when they die, and if the sediment is favourable for their fossilisation, they are soon silted over, and their harder parts preserved more or less intact for all succeeding time. These facts, which to a certain extent apply to all animals, are in an especial degree worthy of consideration when the comparative rarity of ornithic remains comes to be explained. Nevertheless, it is very probable that birds were only beginning to assume the avian form in the latter portion of the Jurassic Age. Some of the Dinosauria, we have seen, were singularly bird-like in some of their structural points. *Campsognathus* (p. 150), for example, had, according to Prof. Huxley, "a light, bird-like head, provided with numerous teeth, a very long neck, small anterior limbs," and, like all its order, "very long posterior limbs." In the beds also, which have yielded so many remarkable reptilian remains, Professor Marsh notes the presence of Dinosaurs with affinities so markedly bird-like that, when their bones are examined apart from their general structure, it is difficult to detect their reptilian character; so that it is quite possible they were birds in everything but the presence of feathers.

From these bird-reptiles it is, however, only a short step to actual reptilian birds. It was an era in the annals of science when, in the year 1861, Hermann von Meyer described a single feather which had been discovered in the lithographic limestone of Solnhofen (belonging to the Upper Jurassic). This species was then—as it is still—the oldest known bird. It was the famous *Archæopteryx macrura*.*

At a later date, an imperfect skeleton (wanting the head) was discovered in the same quarry, and purchased by the British Museum for £600. These bones clearly established its character. It was a bird to which the feather described by Von Meyer had belonged, but, in addition, had marked reptilian characters. At last, in 1876, Dr. Häberlein found a third and more perfect skeleton (Fig. 113) in the Solnhofen quarry. This, after several narrow escapes, was finally acquired by the Berlin Museum for the sum of £1,000, though it is one-fifth smaller than the British Museum specimen, and seems to have belonged to a bird about the size of a ringdove. From a comparison of these precious fragments, the *Archæopteyrx* is now known to have been something smaller than a rook, and, though a bird, to have been no more than the first hint of the many thousands of feathered forms of which it may be regarded as the pioneer. Its vertebræ were bi-concave like those of many reptiles; its tail was long and lizard-like, while the wings had free claws, and the jaws were provided with conical teeth in distinct sockets.

This character stamps it as reptilian, for though several birds which we shall presently meet with had teeth, no species of modern times is so provided, the notches found in the mandibles of ducks, geese, and other forms, being the nearest approach to these ancient appanages of their race. The *Archæopteryx* had no "ploughshare bone," as the last consolidated joints of the spinal column of birds are called. But, instead, the backbone was prolonged into a tail, each movable vertebra or joint of which carried a pair of perfectly-formed quill feathers. That this bird-reptile was capable of flight is proved by the fact that the wings were provided with well-developed quill feathers, each detail of which has been wonderfully well preserved in the fine limestone matrix of Solnhofen. Its wing or forearm is also more avian than reptile; indeed, the form and position of the bones composing this extremity, are just what may be seen in some young birds of to-day, while the brain-cast is more in the direction of birds than of reptiles. Its feet were formed exactly like those of ordinary living birds, and the

* Von Meyer described it as *Archæopteryx lithographicus*. The name *macrura*, or long tail, was subsequently given to it by Sir Richard Owen; and, though this change was not in accordance with the laws of nomenclature, it is almost universally adopted, and may therefore be considered as the name of this "long-tailed ancient wing."

impression of the down which clothed the thighs can be distinctly seen on the stone. As similar though faint markings of down can be detected in the region of the neck, Marsh suggests that it might have worn a ruff of this material. No evidence of feathers is to be found on any other part of the body, so that the conclusion as to its skin being otherwise bare may be accepted as borne out by the few facts which we possess about the *personnel* of this remarkable creature. In brief, the *Archæopteryx* was a bird, though the most reptilian of its class, so that zoologists have formed for it the sub-class Saurornithes,

Fig. 113.—THE REPTILE-BIRD OF THE SOLNHOFEN LIMESTONE, (*Archæopteryx macrura*, Owen.).

(*From the slab in the Berlin Museum.*)

and the order Saururæ, and, from the data supplied by it and other forms, have formulated the theory of the close relationship of birds and reptiles in early times, before they branched off into such widely dissimilar groups as we now know them. It was most probably arboreal, and with its lizard's body, its bird's wings, and "its long reptilian tail floating behind, lined on either side with its row of perfect feathers, and perhaps, withal, gorgeously tinted," as Dr. Shufeldt suggests, must have formed one of the most remarkable denizens of the Jurassic forests.*

Another Jurassic bird with teeth and bi-concave vertebræ is the *Laopteryx priscus* of the "Atlantosaurus beds" (Upper Jurassic) of Wyoming Territory in the Rocky Mountain Region, which, like *Archæopteryx*, is about equally bird and reptile,† though evidently larger than the European form.

Compared with these extraordinary birds and reptiles, the mammals of the Jurassic beds are unexciting, though, in themselves, full of interest. Several disinterred from the Stonesfield Slate were marsupials. One (*Phascolotherium*) was nearly allied to the American opossums. Another (*Amphitherium*) was, like the Triassic Microlestes (p. 134), more akin to the Australian bandicoots (*Myrmecobius*, the banded ant-eater); while a third (*Stereognathus*) is considered by Owen to be an herbivorous hoofed form, belonging to the higher or placental group of mammals. Again, in the Purbeck Beds, upwards of thirty species have been discovered, many of them related to the "flying" phalangers or *Petauri* of Australia (Fig. 114), which, by aid of a fold of skin extending on each side between the fore and hind limbs, can take long leaps from tree to tree; while others find their nearest allies in the opossums or (*Plagiaulax*) in the Australian Kangaroo rats (*Hypsiprymnus*), diminutive nocturnal animals which for the most part feed upon roots. Not only were the mammals of this Period numerous in species, but, from the thickness with which their remains often lie on single slabs, they would appear to have been individually plentiful.‡

Physical Conditions of the Jurassic Period.—The surroundings of the remarkable life of the important Period which has just been sketched, have been frequently indicated in the course of the preceding pages. The plants and animals of the rocks and clays tell, to some extent, the story of the beds in which they are entombed. So far as the British area is concerned, the Lias was, physically speaking, merely a continuation of the Rhætic beneath, and the Rhætic, like the Lias, occupies the basins of the Keuper Marls, which had simply got enlarged and deepened by submergence. Through some invasion of the sea, however, the climate of the Period had begun to alter. This is inferable from the character of the plants and insects found in the Lias, which, from the vast number of fossils embedded in the deposits of that Age, seems to be the sediment of a sea swarming with life, a condition of matters which we have seen by no means held true regarding the Triassic inland lakes; while the presence of cephalopods in the very lowest beds of the Lias suggests, as Mr. Jukes-Browne very properly points out, the presence of that open sea and deep water which these animals

* Marsh: *Geological Magazine*, 1881, p. 485; Seeley, *Ibid.*, pp. 300, 454; Dames, *Ibid.*, 1882, p. 566, and "Palæontologische Abhandlungen," Zweiter Band, Heft III. (1884). In the *Century Magazine* for January, 1886, Dr. Shufeldt has given a good account, with ingenious restorations, of this and other extinct birds. Contrary to the usual opinion of palæontologists, Professor Seeley considers that there is nothing reptilian in the skeleton of Archæopteryx, except that it is less specialised than the skeleton in existing groups of birds.

† Marsh: "Odontornithes: a Monograph on the extinct Toothed Birds of North America" (1880); *American Journal of Science*, Vol. XXI., p. 341, and Vol. XXII., p. 337; and *Report of the United States Geological Survey* for 1881–82, pp. 49–83.

‡ Owen: "Mesozoic Mammals" (*Palæontographical Society*, 1871); "British Fossil Mammals and Birds" (1846); "Jurassic Reptiles" (*Palæontographical Society*, 1851–72), and "British Fossil Reptiles" (1884); Morris and Lycett: "Mollusca from the Great Oolite;" Wright: "Oolitic Echinodermata" and "Lias Ammonites;" Davidson: "Tertiary, Oolitic, and Liassic Brachiopoda" (*Palæontographical Society*, various dates); Phillips: "Geology of Oxford," p. 168, etc., for the fossil remains of the Period.

require, their absence from the Rhætic beds inferring an entirely different state of matters. The dark shales of the Lias, it is assumed, are due to the black mud formed by the extensive denudation of the Coal Measures and the Lower Carboniferous shales, which we know was actually in progress during this Period. The physical geography of the Middle Jurassic was, in many respects, much the same as that of the Age which preceded it. "The country," to use the language of the geologist just mentioned, "which now exhibits the nearest approach to such a scene as Britain must then have displayed is Australia and its neighbouring islands. There many of the Jurassic types still survive. The indigenous mammals are all marsupials: the plants include ferns, cycads, and Araucarian pines. Coral-reefs fringe the shore, and in waters are cestraciont fish, and many of the same molluscan genera as are found in the Oolites, viz., *Phasianella*, *Stomatia*, *Trigonia*, *Corbis*, and *Terebratula*, with others that have a wider distribution. There are, however, no survivors of the Jurassic reptiles, nor of the Ammonites and Belemnites which swarmed in the older seas." Sir Richard Owen has made very similar deductions from premises much the same. A deepening of the sea seems to have followed to be again succeeded by a shoaling; a fact inferable from the scarcity of Ammonites in the great Oolite beds, though in the later Jurassic Ages a good deal of oscillation must have been going on, though these alterations of level, indicated by the character of the rocks and their contained fossils, need not be followed by us.

The region covered by the Jurassic seas may be seen by examining the geological maps showing the deposits laid down in them. These, however, do not always afford an unerring guide to this portion of Liassic and Oolitic physical geography, for denudation has been actively at work since these strata were raised above the level of the ocean. All over the Oolitic regions of the Hebrides and the West of Scotland we find considerable tracts on which the patches of Jurassic strata are evidently mere fragments of those which at one time covered the surface. In these long-lost strata we cannot doubt but that many traces of the plants and animals which existed in that Period must have vanished or

"Their meaning lost,
Save what remains in stone or fragments vast."

Fig. 114.—FLYING PHALANGER (PETAURUS) OF AUSTRALIA IN THE ACT OF LEAPING FROM ONE BRANCH TO ANOTHER.

As to the climate of the Jurassic Age, we have nothing save analogy to guide us. No doubt the pictures painted as to the similarity of Oolitic England to modern Australia are, to a certain extent, justified, though it must be remembered that serious error is likely to ensue if the analogy is accepted too literally. The plants and animals of the ancient Oolite are not those of the modern Antipodean continent, while any evidence supplied by descent is in favour of Australia deriving its present fauna and flora from ancestors which were in recent periods also peculiar to that region. Still, in such broad inferences, we are in a tolerably straight path if we do not go very widely astray. In any case, the climate of the Jurassic Period seems to have been genial, and peculiarly fitted for the growth of the teeming life which distinguished it. Corals built their reefs three thousand miles north of the utmost limits of the modern coral sea in company with animals the nearest kin of which do not nowadays flourish, except in the warm seas of the South.

At present no reptile can exist within the Polar Basin, or comes up even to the confines of it. Yet in Jurassic times, judging from the fossils brought home by the Arctic Expeditions, even the great reptiles, the Ichthyosauri and the Teleosauri (crocodile-like brutes from three to eighteen feet in length) flourished in regions now so cold that not even a frog can live in the chilly air (Fig. 115).*

Fig. 115.—GREAT SEA-REPTILES OF THE JURASSIC PERIOD (RESTORED).

* Vertebræ and ribs of *Ichthyosaurus* and other saurians were found by Belcher and McClintock in the Lias of the Parry Archipelego (Exmouth Island) in lat. 77° 16′ N., and in the Lias beds of Bathurst Island, the saurian named *Arctosaurus osborni*. *Ichthyosaurus polaris* and *I. nordenskjöldii* occur in beds of black bituminous shale referable to the Trias and Lias, and in New Siberia, Kuhn Island, and the southern shore of Clavering Strait,

However, there were Jurassic climates just as there are modern climates. If we do not misinterpret the evidence afforded by some boulder beds in Scotland, there were at that

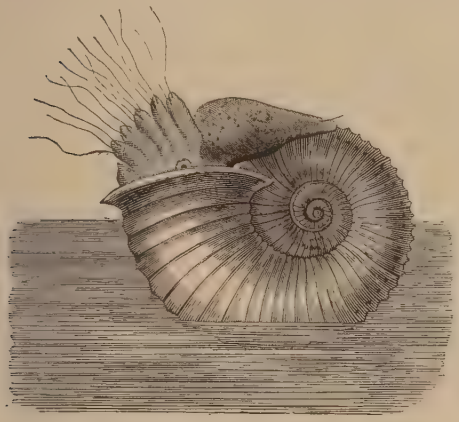


Fig. 116.—AMMONITE RESTORED.

period glaciers in the Highland valleys, and the Northern Jurassic seas display a scantier fauna than that of the more Southern coralline "mediterranean" of Central Europe. Hence, Neumayr has divided the Jurassic deposits of Europe into three geographical regions, each characterised by different species, enjoying different climatic conditions. These are:—(1) The Boreal Province, which comprises the middle and north of Russia, including Petchora—Spitzbergen, New Siberia, Greenland, and the Arctic Archipelago, in which the reptilian bones just mentioned were found. (2) The Central European Province, comprising France, Great Britain, Germany, the Baltic countries, and the regions generally to the north of the Alps. (3) The Mediterranean Province, embracing the Pyrenees, the Alps, the Carpathians, and all the Southern regions.

From the first-named area corals and the *Aspidoceras* and *Oppellia* groups of Ammonites are wanting, a circumstance explicable only on the ground of deficient temperature. In the Central Region these fossils are markedly present, while the chief characteristic of the Mediterranean Province is the great abundance of Ammonites belonging to the Heterophylli (*Phylloceras*) and Fimbriati (*Lytoceras*) groups.*

Seas, and lands, and rivers, swarming with reptiles so huge, while the air was thick with flying lizards and toothed birds, must have been, to modern ideas, anything but quiet neighbourhoods (Figs. 102, 103, 115). There is, nevertheless, nothing in the history of these uncouth brutes to justify the highly-coloured pictures of the eternal warfare going on among the inhabitants of lagoons and lakes, woods and upper air. Most of them seem to have been either insectivorous (Fig. 101), or, when not fish-eaters, for the most part vegetable feeders. The great, no doubt, devoured the little, and the cruel beak and sharp teeth of the *Rhamphorhynchus* (Figs. 102, 114) must have played havoc with the fishes of the Jurassic pools. But the pterodactyles, or the *Archæopteryx*, or the much larger *Laopteryx* (of which only an imperfect skull has been found), if not insect

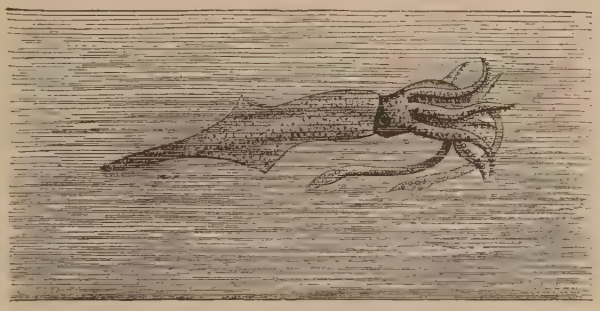


Fig. 117.—BELEMNITE RESTORED.

off the shores of East Greenland, and other places in the Arctic Regions, beds containing Ammonites and other characteristic Jurassic fossils have been noticed.

* Neumayr: *Jahrbuch der Geol. Reichsanstalt* (1871), pp. 297, 451; *Denkksch. der Wiener Akad.* (1883), p. 277, etc. In this paper the author has attempted to extend these provinces into zones or belts stretching round the globe. But his success has not been so marked that it is, for the present, worth tracing these "homoiozoic zones" in detail.

eaters, were not—so far as we can tell—more ferocious than the fish-eagles, or condors, or vampire bats; and, except that they could come on land, the *Ichthyosaurus* and the *Plesiosaurus* were, in all likelihood, less carnivorous than the savage grampus or killer (a cetacean which preys on the other whales), or the alligators and crocodiles, with whose habits we are all familiar, or the boa-constrictor and numerous modern snakes. Still, elephantine reptiles could not have been agreeable co-inhabitants of any possible kind of world, and had man been then on the earth his puny arms must have been able to oppose only a feeble resistance to such "monstrous efts."

Science and Economic Aspects.—The total absence of volcanic outbursts through the English Jurassic strata gives a flatness to the scenery of the country occupied by them in spite of the numerous faults and other dislocations to which they have been subjected. One bed follows another, perfectly parallel, and without any unconformity, often over wide stretches of country, so that the conclusion is inevitable that the time during which they were laid down was one of those comparatively tranquil periods which every now and again intervene between a series of paroxysmic ages. Here and there we find evidence of flooded rivers and torrents, which brought down trunks of cycads and quantities of mountain *débris*, though in no more pronounced form than obtains at present. Indeed, unless we except the Granitic upheavals, on the top of which the Oolites of the Hebrides have been tossed, Oolitic Great Britain seems at this date—and subsequently—to have been a land as peaceful as the presence of so many uncomfortable reptiles admitted of its being. Yet the Jurassic Age was not altogether without disturbance from below, and considering how, even at the present day, scarcely a year elapses without lava being vomited forth in some region of the earth, it would have been surprising had the long period during which the rocks from the Lias to the Wealden were being accumulated, been an exception to this normal state of affairs. Accordingly, we are prepared to find that the marine beds of Cutch in India—a series of rocks which range from the Lower Oolite up to the Portland*—are penetrated and interstratified by igneous outbursts of various dates, while the mere fact of the typical Jurassic strata reposing on the flanks and peaks of the crumpled Jura and Erzgebirge is proof enough that the succeeding ages were at times and in certain quarters wild enough. It thus follows that, unless in such elevated regions as these, the Jurassic beds rarely rise to more than 900 or 1,000 feet, and are characteristic chiefly of rolling hill and dale, and ridges on which the limestones and clays have disintegrated into rounded knolls, while the rain has swept the *débris* down their sloping sides or accumulated it in the unbroken valleys below. Sometimes when the limestone has resisted the action of the weather, the slopes of the Oolitic vales present a series of escarpments one above another, the intervals between them being occupied by the green turf formed on the clay, or shales, or marls, which alternate with them. Nor, when wooded glens and gorges cut by the drainage of the district add variety to an Oolitic landscape, has the traveller in search of the picturesque any reason for bewailing his evil fortune in not finding it in the Cotswolds or in the neighbourhood of Bath. In Scotland, where the Liassic and Oolitic strata often come in close contiguity with older formations, the variety which they impart to the scenery is remarkable. On the western coast the comparative richness of the soil which their decomposition affords, as well as their low level, mark them sharply from the Cambrian and Silurian mountains which surround them.†

Indeed, the character of the Jurassic beds and their contents has a singular influence on the habits of the people whose homes are placed on them. This was noted by Dean Buckland in the early days of geological

* Medlicott and Blanford: "Geology of India," p. 253.

† Geikie: "Scenery and Geology of Scotland," p. 225.

science, when Final Purposes and creative Design played a larger part in its speculation than they do in these more materialistic times. North and south of a line drawn through England from the coast of Dorset to the mouth of the Tees, along the base line of the Jurassic System, the island would be divided into two regions widely different as regards their physical features and economic aspects. The bold mountainous Palæozoic tracts north-west of this line are lands full of coal, iron, lead, tin, and copper. To the south-east of this line the Neozoic ground is rarely lofty, seldom rich in mineral wealth, but, owing to its possessing a richer soil, is a land of graziers and agriculturists; while the country which is poorer on the surface but wealthier in subterranean treasures is inhabited mainly by miners and the "hands" who smelt the metals and raise the coal, and apply these materials in a hundred industrial pursuits.

Descending, however, from the abstract to the concrete, the Trias varies considerably from a tillage point of view. The Lias is, for example, often poor, the "coombs" and "wolds" being usually covered by stiff cold clays, while the Oolites, especially when the subsoil is limestone, are generally dry and fertile. The Lias clays are therefore best utilised as grazing lands, being too stiff for easy ploughing, and yet so retentive of moisture that they form excellent meadows. Hence many of the oldest pastures in the centre of England are on the Lias—grassy slopes "intersected by numerous footpaths of ancient date that lead by pleasant hedgerows to wooded valleys and old timbered farmsteads." The Middle Lias or Marlstone is, however, owing to its lightness (being a mixture of clay and sand, with some amount of lime), often a very fertile soil, as may be seen in the country around Banbury. Accordingly, the Middle Lias country, where it forms an escarpment overlooking the Lower Lias, is marked by a stripe of well-cultivated land, "often dotted with villages and towns, with antique churches and handsome towers, built of the brown limestone of the formation." The flat tops of the Oolitic Downs, when they rose to a considerable height, as in the Cotswold Hills, were until lately devoted to old pastures, a circumstance from which originated the many woollen factories of Gloucestershire. But nowadays they are, to a large extent, cultivated, though the broad belts of Oxford and Kimmeridge Clay that lie between the western part of the Oolite and the base of the Chalk escarpment are largely devoted to grass, while the broad heathy tracts of the Yorkshire moors are underlaid by the Lower Oolites, and the fertile Vale of Pickering is occupied by the Kimmeridge Clay.*

The Cornbrash (that is, a compact cream-coloured limestone with occasional bands of marl and clay, breaking into "brash" or fragmentary rubble when it forms the subsoil and is exposed to atmospheric influences) is, as its name signifies, good corn land, owing to its great abundance of phosphate of lime, due, in part at least, to its many organic remains. It also contains a much larger amount of sulphate of lime than the other Oolites, circumstances to which may be attributed the fact that it yields, on an average, twenty-five per cent. more wheat than the Great Oolite, and from twenty-five to fifty more than the Inferior Oolite of the Bath or Lower Oolites, to which it belongs, while its superiority in raising barley and oats is even more marked.

In Oxfordshire the Marlstone, which is often highly ferruginous, takes the form of an oolitic brown hæmatite, which is quarried as an iron ore at Fawler, and in the Cleveland district the same rock contains an ironstone often from twelve to seventeen feet in thickness, and containing from twenty-eight to fifty per cent. of metallic iron. Middlesborough is the chief centre of the Middle Lias iron industry. In Northamptonshire the lower beds of the Inferior Oolite contain much ferruginous sand and ironstone. The Upper Lias at Whitby contains jet, which is mined to the value of about £20,000 per annum (Vol. I., p. 58), and in Yorkshire both the clays of this formation and the alum

* Ramsay: "Physical Geology and Geography of Great Britain," pp. 571—72.

shales proper yield, on treatment with sulphuric acid, large quantities of "alum." This is, chemically, sulphate of alumina, derived from the pyrites or sulphuret of iron found in it. At one time the Kimmeridge Clays were treated with a like intent; and in former days, when sulphur was held at a much higher price than now, the Liassic strata were utilised —or attempted to be utilised—for the extraction of this substance. The same (Kimmeridge) bituminous shales have been distilled for naphtha, and the nodules of argillaceous limestone, in which the clays abound, are converted into Roman or hydraulic cement. The "Coprolite Bed" of the Portland series is worked at Speeton Cliff, on the Yorkshire coast, for the sake of the coprolites, which yield from fifty-seven to sixty-one per cent. of phosphates (Vol. I., p. 56).

The Jurassic system is also rich in building stones. Those of Bath or Portland are employed for facing houses in the South of England. The "Bath freestone" furnishes the materials of which the beautiful city of Bath is chiefly built, and near Corsham is worked underneath the Forest Marble by means of shafts and tunnels. Cheltenham is built mainly of the Inferior Oolite "roestone." The Portland Stone is derived from the "Whit-bed," an upper member of the Portland series. It is a durable limestone. The "Base," or "Best bed," is also in demand as a building stone, though it is less durable than the Whit-bed. The "Roach" beds are composed of stone still more durable, but, owing to the honeycombed character of the rock, caused by the casts of fossils, it is not of much economic value, while the lower limestones, as well as the "curf," owing to the layers of chert which interstratify with it, are of no use to the mason. The Caen stone of Normandy also belongs to this group. The Lower Oolite at Stonesfield, Sevenhampton, Collyweston, etc., yields sandy slates or flags, which have come into favour for roofing buildings in the Tudor or Gothic style. Mortar is obtained by burning the limestones.

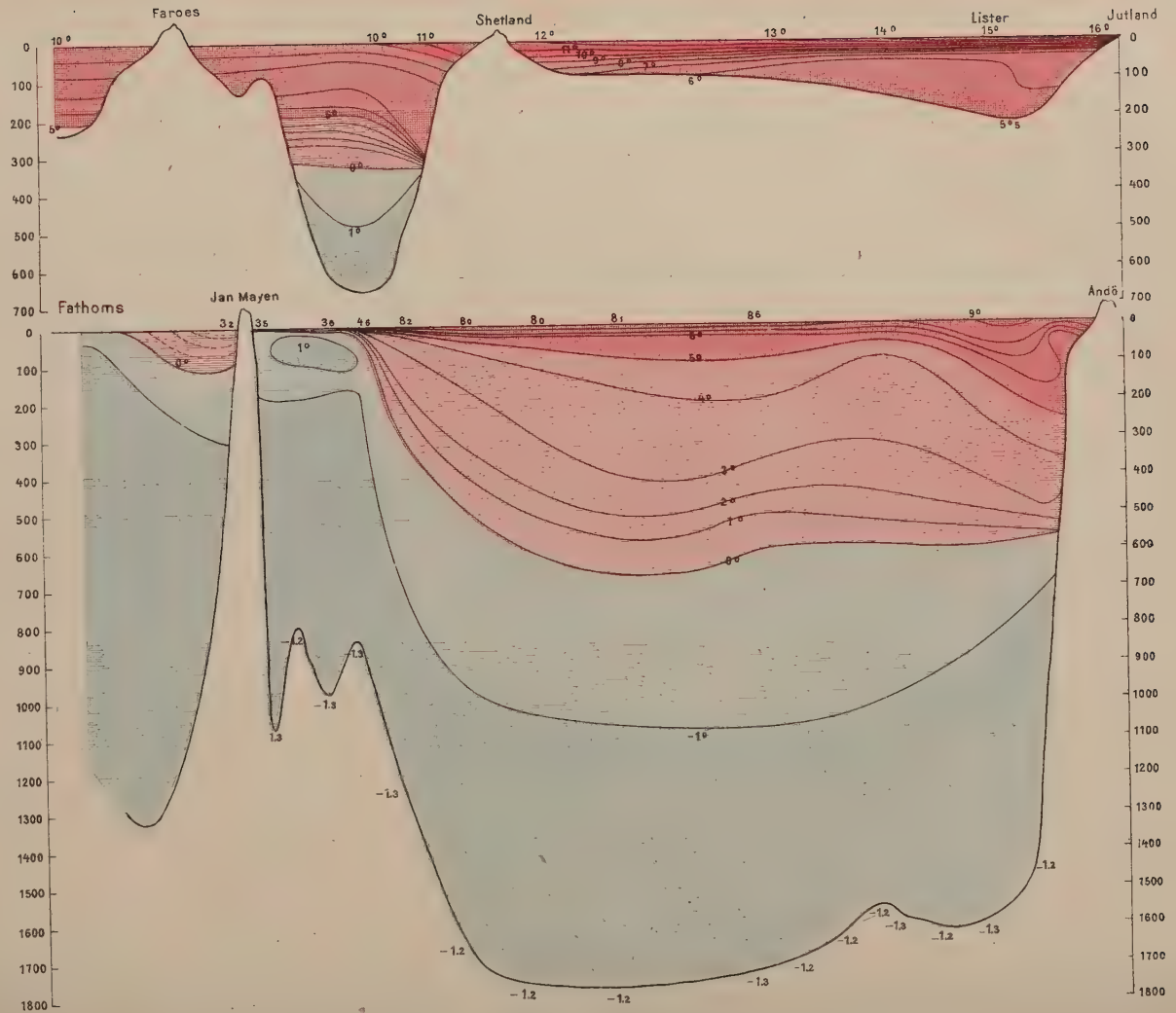
The "Sussex" or "Petworth marble" is obtained from the lower Wealden beds, and the term "forest marble" has been applied to the hard limestone, admitting of a good polish, which is found among the bluish flagstones, slates, clays, and silicious sandstones of Wychwood Forest, in Oxfordshire. The "Landscape marble" of the South-west of England is a Liassic rock of a similar character. The "Purbeck marble," a marly limestone crowded with shells of *Paludina carinifera*, was once much used in church architecture throughout the Southern counties of England.

Some of the Jurassic limestones have been tried as lithographic stones. But with the exception of the famous ones of Solnhofen, Pappenheim, Kelheim, Dichstadt, and other parts of the German White Jura (p. 143), none of them have been very successful. These lithographic "slates" seem to belong to the horizon of the upper division of the Kimmeridge Clay, celebrated for the many important organic remains which they have yielded, the wonderfully fine texture of the rock, and the absolutely placid manner in which it has been deposited, enabling even the impression of jelly fishes, not to say molluscs, crustaceans, insects, many fishes, several tortoises, saurians, flying lizards, or pterodactyles, and the celebrated *Archæopteryx*, to be preserved in the beds. (Fig. 118.)

The hard, gritty sandstone, in which have been dug the Caves of Hercules, near Cape Spartel, in Morocco, is, most probably, like the bulk of the limestone of Gibraltar Rock, of Lower Jurassic age. Into this coarse, firm stone the natives have for ages—no doubt long before the Arab, or even the Roman, invasion of Mauritania*—been hewing for the purpose of cutting the little millstones with which they grind their corn in hand querns of a character almost identical with those at one time extensively used in the North of Scotland, and still to be seen in Shetland and the Hebrides.

Fuller's-earth—a compound of alumina and silica, *plus* about twenty-four per cent. of water—derives its name from having at one

* It is, nevertheless, doubtful whether this cave was the *specus Herculi sacer* of Pomponius Mela. M. Tissot (*Recherches*, etc., p. 52) inclines to place this spot elsewhere.



TEMPERATURES (CELSIUS) OF THE EUROPEAN NORTH SEA.

(AFTER MOHN.)

time been extensively used in "fulling"—*i.e.*, the cleansing and scouring of woollens—owing to its property of absorbing grease.

Lastly, the Jurassic is a coal-bearing System. The "Kim" coal of the Kimmeridge Clay is little better than a bituminous shale, though it burns with a dull, smoky flame, and has been distilled for the extraction of the naphtha products. But at Brora in Sutherlandshire, Gristhorp in Yorkshire, and at other places, true coal has been mined out of Oolitic formations. The Brora field was worked for more than a century but, mainly owing to the quantity of iron pyrites which the coal contains, proved unprofitable and was abandoned. One of the seams (composed of crushed *Equisetites*) is three and a half feet thick, and there are several others of inferior quality resting upon it.

Some of the coal fields of Southern India, and those of Borneo (Labuan), and Zebu in the Philippine Islands, are believed to be of Oolitic age, while it is all but certain that several of the coal-bearing areas in Japan and China now regarded as Carboniferous will, when investigations are more complete, be assigned to the same system. Some of these, particularly those of Labuan (which, though worked, have not been a commercial success) and Zebu, may, however, be of Tertiary age.

Though some of the principal deposits of rock-salt are in the Trias, those of Salzburg are in limestone of Jurassic age, those of Stassfurt in Permian beds, while those of Wieliczka are in Tertiary sand, a period to which must also be assigned the deposits from which the city of Fez has for ages been supplied.

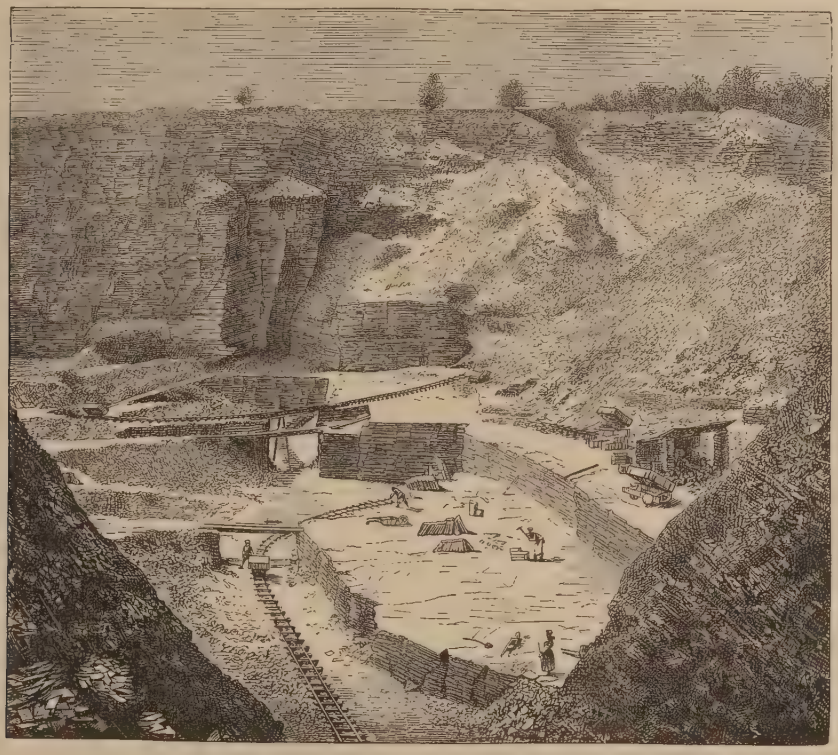


Fig. 118.—LITHOGRAPHIC LIMESTONE QUARRIES OF SOLNHOFEN IN BAVARIA.

CHAPTER X.

The Mesozoic Rocks: The Cretaceous System.

General Characteristics of the System—Its Range—Its Classification and Foreign Equivalents—Life of the Cretaceous Period—Description of some of the chief Plants and Animals of the System—The Greenland and Laramie Floras—The Appearance of Plants with Netted-veined Leaves belonging to Living Genera—Proteaceæ, etc.—Foraminifera—Chalk—Flints—New Species and Genera of Ammonites—First Appearance of Teleostean Fishes—Reptiles—Iguanodon, Mosasaurus, Hadrosaurus, Lælaps, Discosaurus, True Crocodiles, etc.—Toothed Birds of America—Ichthyornis, Hesperornis, etc.—Absence of Mammals—Physical Geography of the Period—Chalk and Flints—Mistaken Generalisations about our "Living in the Cretaceous Period"—Climate of the Period—Cretaceous Provinces—Scenic and Economic Aspects of the System—The Chalk Downs—Various Soils of the Cretaceous System—Influence on Health—Chalk Hills—Coalfields of the Period—Iron—Chalk and Flint—Building Stones—etc.

The system of strata which, from the presence of chalk, not as a predominant member of the series or even an important one, has been termed the Cretaceous,* is, in all parts of England except in the South, separated from the Jurassic by a well-marked unconformity, so far as the strata are concerned, and by a palæontological break in the fossil character of the two systems. Nevertheless, as illustrating how artificial and tentative our geological classifications are (and must always be), we find in Dorsetshire an unbroken sequence from the highest member of the Jurassic to the lowest member of the Cretaceous, showing that, whatever might have been the case elsewhere, in this part of England at least the one Period graduated imperceptibly into the other. In Nature we do not usually find formations or systems so clearly cut off from one another as the colours or the sections of the geological maps might lead the novice to infer was the case. These graphic representations are all more or less approximations to the truth, for it is seldom that transitions between contiguous beds do not occur. Thus the Purbeck at the top of the Jurassic and the Wealden at the base of the Cretaceous (though at one time both were included in the Jurassic) are, in truth, more or less passage-formations, containing as they do fossils characteristic of both Systems. It is, indeed, an open question whether some of the Upper Jurassic rocks of Southern France and the southern sides of the Alps, to which Oppel has given the name of "Tithonian"† (p. 143), are not of the same nature. These consist of a uniform series of strata, chiefly limestones, distinguished by a set of Ammonites and other cephalopods of a mixed character, and in the so-called "Diphya limestone" by the peculiarly perforated *Terebratula diphya*. However it is as well to class the Wealden with the Cretaceous, with the proviso that the ordinary classification is more or less artificial, or at least less natural than Nature itself. The French geologists regard the Tithonian as Cretaceous, while the Austrians are divided whether to consider them as Upper Jurassic—the top of the Alpine Jura—or as contemporary with the Wealden.

The series of formations classified as Cretaceous have a wide range. In England they cover much of Norfolk, Suffolk, Cambridge, and Hertford, all of the Yorkshire Wolds, the Chiltern Hills, the North and South Downs, Salisbury Plain, and the southern section of the Isle of Wight (Figs. 122, 124), with detached areas of smaller size here and there. In Ireland they occur in Antrim, Tyrone, and Londonderry, overlaid by basaltic rocks of

* Latin *creta*: it is the *Kreideformation* of the Germans; the *Craie* or *Crétacé* of the French geologists.

† "Tithonische Stufe": a classical conceit from Tithonus, the nephew of Priam, who married Eos, the goddess of Morning—to signify that in the beds so named the dawn of the Cretaceous System is foreshadowed.

Tertiary age, and, as the outlying patch near Draperstown shows, before denudation washed them away they most probably extended much farther than their present range.* The only traces of Cretaceous rocks *in situ* hitherto discovered in Scotland are in the Island of Mull, and at Morven on the adjoining mainland,† though the scattered flints on the fields of Banffshire and Aberdeenshire tell of their existence in the past. But on the Continent of Europe they have a far wider distribution, crossing as they do under the waters of the Channel into France, and thence northward through Belgium, Holland, and the south of Scania into Sweden, and eastward through Germany, Poland, and Russia, though in the whole of this vast area it is seldom that they appear on the surface, being covered by rocks of a later age. Indeed, over much of the country once covered by the Cretaceous formations denudation has been steadily at work. In Denmark, for instance, the Faxoe Limestone and the Saltholm Chalk are about the sole representatives of the system actually *in situ*, but every field in Seeland and most of the other islands is scattered with flints and other remnants of the vanished rocks. If the Geological Map of Central Europe (*q. v.*) is studied, it will be seen that Cretaceous beds repose on the flanks of the Riesengebirge, the Harz, and the Carpathians run from Westphalia eastward, and through Bavaria and Tyrol into Austria, though in belts much narrower than elsewhere; and besides these, offshoots from the Rhine Valley appear on the southern side of the Alps and along the crests of the Apennines. The System also covers some portions of the south and west of France and the east of Spain, and in Southern and South-Eastern Europe finds a considerable development in Sicily, Dalmatia, Istria, Greece, Bulgaria, and the southern shores of the Black Sea.

In Asia it appears in Asia Minor, Persia, Palestine, India, and other countries; while in Northern Africa the Mediterranean area extends over a large portion of Algeria in the shape of plateaux with terraced escarpments, and in Morocco Cretaceous beds occur — among other places less known —not far from the crumbling town of Al-K'sar-el-Kébir on the banks of the El-Koos River, which, winding as it does over a plain, at the seaward end of which is El-Araich (Laraiche) embosomed in orange-groves, the ancients represented as the serpent which guarded the Golden Apples of the Hesperides.‡ In Australasia the Cretaceous System covers great areas in Queensland, New Zealand, and other colonies; and in North America (though there is no representative of the White Chalk), the Cretaceous System is now known—contrary to the earlier beliefs of geologists—to stretch far, and attain an enormous thickness, especially in the southern and western regions of the United States and Canada. In the Dominion it covers much of the prairie country of the North-West Territories between Manitoba and the Rocky Mountains, and on the Pacific extends from Vancouver Island to the Queen Charlotte Islands, in both of which extremities it contains large coal-beds. In the eastern portion of the continent it is more sparsely developed, but it stretches far north, having been detected near the mouth of the Mackenzie,§ and on the western shores of Greenland, more than

* Barrois: "Recherches sur le Terrain Crétacé Supérieur de l'Angleterre et de l'Irlande" (1876).

† Judd, *Quarterly Journal of the Geological Society*, Vol. XXIV., p. 728.

‡ This was not the only serpent-river in Africa. In Tunis—the African Province of the Romans—the River Bagrada (Wad Medjerda) winds serpent-like along the plain which stretches from the Numidian Mountains to the sea, one day dry, another day a rushing torrent of water, rendered yellow by sandy mud. Hence the legend of Attilius Regulus and his affrighted soldiers striving in vain against the monstrous snake that haunted its banks. At the commencement of the Christian era this river emptied itself into the sea a few miles north of Carthage. Four times since that period it has shifted its outlet, and it now debouches close to Porto Farino, many miles northward as vaguely as when Statius described how "Pœnos Bagrada serpit inter agros."—Tissot: "La Province Romaine d'Afrique," Vol. I. (1884), pp. 57 *et seqq.*; Graham and Ashbee: "Travels in Tunisia" (1887), p. 45; Temple: "Excursions" (1835), Vol. I., p. 253.

§ Richardson: "Arctic Searching Expedition," Vol. I., p. 186, where some of the fossils figured seem not Tertiary, but Cretaceous forms.

two hundred and fifty miles within the Arctic circle. The entire continent of America is, however, as yet too little explored for anything like a complete idea of the range of the Cretaceous beds to be ascertained. We know, among other regions over which the old Cretaceous seas extended, New Zealand,

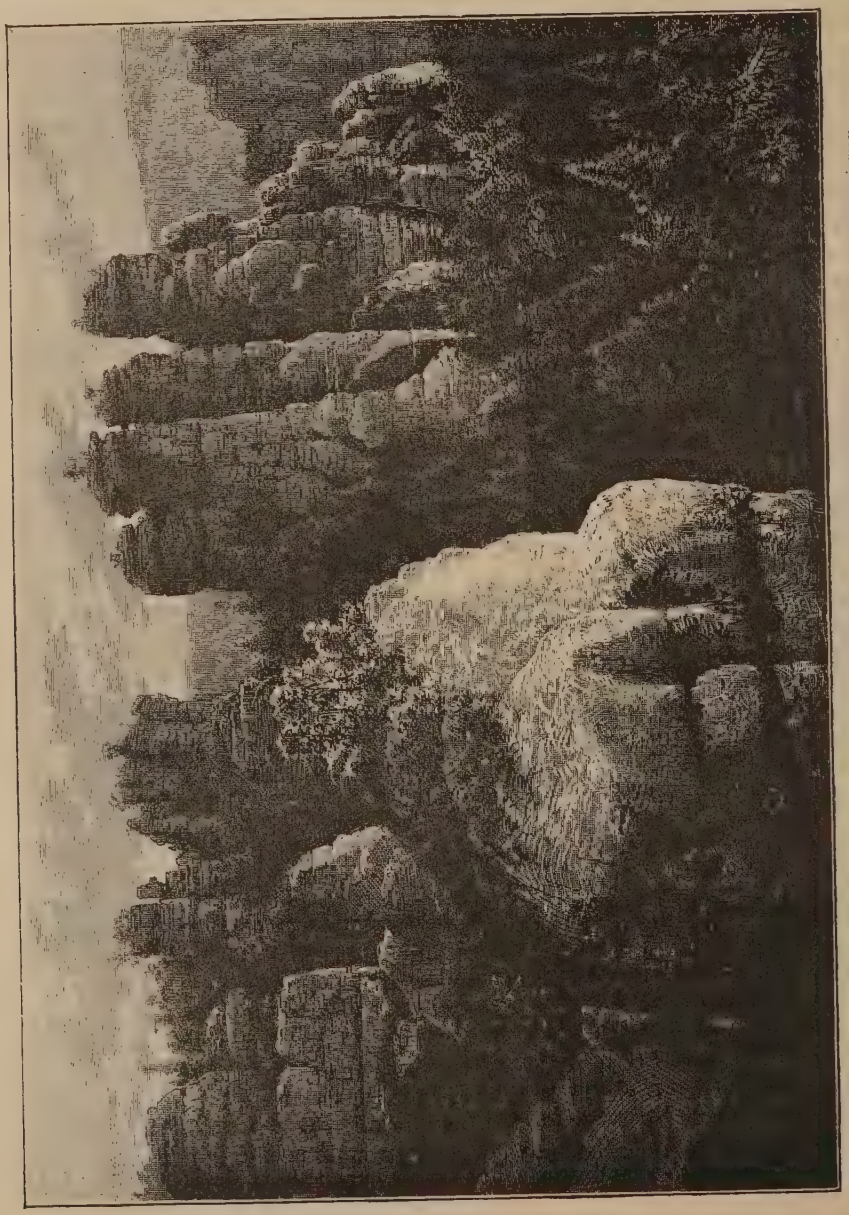


Fig. 119.—QUADERSANDSTEIN ROCKS IN SAXON SWITZERLAND: MARTERSTELLE FROM THE BASTEIBRÜCKE.
(*From a Photograph.*)

Queensland (the "Desert Sandstones" and other rocks of uncertain position), and Natal may be mentioned, the beds on this coast of Africa being very similar to those of Trichinopoly, the Narbada Valley, and Pondicherry in India, which strata again have a large number of fossils identical with those of the Upper Cretaceous of Europe. The Lower Cretaceous is confined to a small band in Cutch, containing two species of Ammonites found in the Neocomian of Europe.

The rocks composing this widely-scattered System are singularly diversified in their structure. The sameness of lithological structure which we found so characteristic of the earlier strata (formed as they were of the worn-down materials of the Igneous and Primary rocks) no longer prevails. In the evolution of the globe the greater diversity of geographical conditions has tended to impart an equally varied appearance to the rocks laid down during the later ages of the world's building. Moreover, as one rock is to a large extent—and wholly when it is a "clastic" one (Vol. I., p. 51)—made out of its predecessors, it must necessarily follow that the newer beds, having a greater choice of materials to select from than the older ones, will be of a less and less monotonous texture the nearer and nearer we approach our own times.

In England the Cretaceous strata attain a thickness of about 4,100 feet, but on the European Continent their aggregate depth is not less than 6,400 feet, while in the United States Territories of Utah and Wyoming they show for upwards of 13,000 feet an unbroken succession of marine, fluviatile, and terrestrial beds. In England also the Cretaceous beds, from the lowest to the highest, are, for the most part, conformable; though, as Mr. Jukes-Browne has shown, in the case of the Grey Chalk of Cambridgeshire and the overlying Lower White Chalk, there are breaks here and there marked not only by the physical unconformity of the contiguous strata, but by an equally abrupt change in the fossil contents above and below the break. There is also in the south of England an unconformity between Upper and Lower Cretaceous. As, however, we shall see by-and-by, there were in Europe four tolerably distinct areas of deposition during Cretaceous times, each of which had its own facies and betokened, not only a different series of conditions from the others, but in some respects a different climate and a wide interval of time.

Classification of the Cretaceous System.—The almost universal mode in which the various formations entering into the composition of this System are arranged is into the *Lower* and *Upper Cretaceous*. Under the former are bracketed the (*a*) Wealden and (*b*) the Lower Greensand, while the (*c*) Gault, the (*d*) Upper Greensand, the (*e*) Chalk Marl, the (*f*) Grey Chalk, the (*g*) Lower White Chalk, the (*h*) Upper White Chalk, and the (*i*) Maestricht Beds, are the leading members of the Upper division. A somewhat different classification has been adopted on the Continent, with a different set of names from those given to the beds in England. These equivalents will be duly given in the following synopsis, though in the present condition of knowledge it is unnecessary to apply them to the British Cretaceous series.

(*a*) *Wealden.*—This important, though local, Formation derives its name from being largely developed in those parts of the English counties of Surrey, Kent, and Sussex known as the Weald. Most of this region has long ago passed under the plough; but much of it is still well wooded, especially in the west, though few of the trees are of primeval growth. Nevertheless, remains of the old forests of Tilgate, Ashdown, and St. Leonards, still remain, and, down to a comparatively late historical period, Sir Andrew Ramsay observes, both clays and sands were left in their native state, partly forming those broad forests and furze-clad heaths which covered almost the entire area of the Wealden Formation. The very name "weald" or "wold" is an old English term signifying a woodland. Even as late as last century or the beginning of this, "these wild tracts were famous for highwaymen and bands of smugglers, who transported their goods to the

interior from the seaport towns of Kent and Sussex by means of relays of pack-horses."

Though much denuded, the actual or former continuity of the Wealden can be traced for a long distance north and south, east and west. From Dorsetshire and Devonshire in the south-west of England, it extends for about two hundred miles east to the district in the vicinity of Boulogne in France known as the Bas Boulonnais in so identical a form, that there cannot be a doubt as to the French and English Wealden having formed one area of deposition and one unbroken streteh of land before the Channel cut them in two. In another direction it extends nearly 200 miles, from Surrey and Hampshire to Beauvais in France. But the Wealden is not confined to this area, though the beds found in the 20,000 or 30,000 square miles which it covers were more probably contemporaneous than those outside its limits. However, both in Belgium and North Germany (Harz, Westphalia, and Hanover) we find beds quite comparable with the Wealden. The Diester Sandstone (perhaps an equivalent of the Hastings Sands) contains a great many terrestrial plants and seams of workable coal, while the animals are entirely of fresh-water genera.*

It is in England, nevertheless, where this lowest member of the Cretaceous System is most typically developed. There the bottom of the Formation is sandy, though with layers of clay here and there, and even limestone and ironstone, which in former times (p. 118) were mined to supply the furnaces of the Sussex Wealden. This sandy division of the formation is known as the *Hastings Sands*, and is itself divisible into the Fairlight Clays, the Ashdown Sands, the Wadhurst Clays, and the Tunbridge Wells Sands, part of which forms those curious weathered rocks in the neighbourhood of Tunbridge Wells, East Grinstead, and other portions of Sussex.

The upper portion of the Wealden, which is from 150 to 1,500 feet thick (the lower being from 500 to 900 feet), is, on the other hand, for the most part clayey, though with occasional sandy layers and limestones, which are known as Sussex marbles, composed almost entirely of two species of freshwater shells —*Paludina sussexensis* and (in the Petworth and Bethersden marbles) *P. fluviorum*. This division is known as the Weald Clay, which is in places of great depth, and everywhere of extreme tenacity. It was this soil which William Cobbett anathemised in his usual robust manner. "From Ewhurst," he tells the readers of his "Rural Rides," "the first three miles was of the deepest clay that I ever saw to the best of my recollection. I was warned of the difficulty of getting along; but I was not to be frightened at the sound of clay. It took me a good hour and a half to get along these three miles. Now mind, this is the real Weald, where the clay is bottomless." In half a century matters have somewhat improved. Yet even now, in spite of Macadam, a Wealden road is so bad, and the Weald soil, as a rule, so moist, that the geologist who pursues his investigation, as the writer of these lines did, in mid-winter, has little difficulty in realising the assurances of residents, who do not even claim to be the oldest inhabitants, that not many years ago it was quite possible to get stuck fast in these byways after a spell of wet weather.

The Wealden is throughout nearly a fresh-water Formation, with a few brackish and even marine beds in its lowest part. In reality, it seems to have been the delta of one or more rivers, discharging themselves into an almost land-locked lake, to which the sea had only partial access, and then only at the earliest period of the deposition of the sediment brought down by the streams. These rivers might have flowed from different directions, though the probability is that they eroded the rocks of what remained of the Western extension of Europe into, or across what is now, the Atlantic, and that the mud of the Wealden is that of a long-vanished continent. But large though the area of the Wealden is, and deep though some of its

* Credner: "Ueber die Gliederung der obern Jura und der Wealdenbildung in Nordwestlichen Deutschland" (1863); Struckmann: "Die Wealden-Bildungen der Umgend von Hannover" (1880); Schenk, *Palæontographica*, Vols. XIX., XXIII.; etc.

deposits are, there are modern deltas which may have been a much shorter time in forming, which are quite worthy of being compared with it. Witness, for example, those of the Ganges and Brahmapootra, the Niger and the Nile in Africa, the Orinoco in South America, and the Mississippi in the northern part of that continent (Vol. I., pp. 315–318), some of which are smaller than the area of the Wealden, while others are very much larger.

The fossils of the Wealden are those of deltas—fresh-water fishes, shells, and crustacea, and the bones of land animals which have been washed down by a river and embedded in the sediment at its mouth, with the cones of pine-like trees, the fruits, trunks, and leaves of cycads, tree ferns, herbaceous ferns, equiseta, and the like. Many reptiles, chiefly Dinosaurs, have been disinterred from its clayey beds, among others, the same species of *Megalosaurus* (*M. bucklandi*) which occurs in the Stonesfield Slate, with numerous others belonging to the genera *Regnosaurus, Hylæosaurus, Polacanthus* — which probably was sheathed in mail — *Pœcilopleuron,* etc., including many crocodilians and turtles, and several winged lizards, these dragons of the air being still numerous. But one of the most remarkable of all the Wealden reptiles was the *Iguanodon mantellii,* so named after Dr. Mantell, who did so much for the exploration of this and other Formations.* It was a huge brute, often nearly 35 feet long and 20 feet in girth, with a tail 15 feet, and a head 3 feet long, while specimens have been discovered even larger. Yet, like its humble living ally, the *Iguana* of South America, the Iguanodon was probably an herbivorous lizard, which moved freely above the surface, intent only on devouring the cycads, and ferns, and *Pinites* of the Wealden river swamps. Like the *Megalosaurus,* it was a Dinosaur, which, from the disproportionate length of its hind feet, probably walked on these (p. 134). Remarkable as are the reptilian remains of the Wealden of England, discoveries during the year 1878 disclosed the existence of an even more remarkable series in Belgium. In hard clay, filling up some ravines—between Mons and Tournai—in the Carboniferous rocks near Bernissart, at a depth of more than 1,000 feet below the surface—and which, from their remains, seem wholly or for the most part of Wealden age—the bones of turtles, fishes, Dinosaurs, Plesiosauri and Ichthyosauri of several species, ten Pterodactyles, and a host of other reptiles, with fishes, plants, etc., were found. They had got embedded in those valleys which were open during Cretaceous times, and were brought to light during the mining operations. Among the animals thus entombed was the huge *Iguanodon bernissartensis,* the skeleton of which, now in the Brussels Museum (Fig. 120), was 14 feet 2 inches in height, and 23 feet 9 inches in length. Like the rest of its genus, it was clearly, from the structure of its teeth, herbivorous, its powerful tail serving most likely as an organ of propulsion, or, like the spurs or the digits of its fore-paws, as a means of defending itself from the more fleshly-minded reptiles around it. Its very thighs must have been six or seven feet in circumference.†

An attempted restoration of the Iguanodon is made in Fig. 121, which is in agreement with a figure erected by Mr. Waterhouse Hawkins in the Crystal Palace at Sydenham, near London.

The Continental geologists know the Wealden either under that name, or—as in Germany—by the equivalent designation of Wälderthon-Bildung. But both it and the Hils,‡ which is the German representative of the Lower Greensand, are now generally

* Mantell: "Fossils of the South Downs" (1822); "Illustrations of the Geology of Sussex" (1827); "Geology of the South-East of England" (1833); "Wonders of Geology" (1848); "Medals of Creation" (1854); Topley: "Geology of the Weald" (1875); Dixon's "Geology of Sussex," *Memoirs of the Geological Survey* (1878); etc.

† These facts are from M. Dollo's "Les Dinosauriens de Bernissart" (1882–84), and other papers in the *Bull. de l'Acad. Roy. de Belgique,* 1882–86. See also Dupont, *Bull. de l'Acad. Roy. de Belgique,* 1878.

‡ *Hils,* comprising the Hils conglomerate and, above that, the Hils thon (or clay), is from the Hils Basin in Hanover.

bracketed under the general title of *Neocomian*,* applied to them by the French geologists. In this classification the Wealden beds are the Lower Neocomian; the Lower Greensand which follows it the Upper Neocomian.

(*b*) *Lower Greensand.* — This formation derives its name from the sands of glauconite, or some other greenish-coloured (chloritic) mineral, which occur in it sparingly, and by no means so invariably as the term might suggest. The division between it and the Wealden is very slight, and not unfrequently the one passes by insensible gradations into the other. In reality, the Lower Greensand, as we know it in Great Britain, consists of an alternation of sands, sandstones, and clays, with beds of limestone and ironstone here and there to the thickness of about 850 feet, and the general colour of the Formation is not green, but either dark-brown or red.†

The Lower Greensand, unlike the Wealden, is wholly marine, and its most characteristic fossils consist of the shells of cephalopods, such as *Ammonites speetonensis, Ancyloceras gigas, Belemnites jaculum, Toxaster complanatus*, and other species, disinterred so abundantly from the clays of the Speeton Cliffs in Yorkshire, or less sparingly from those sandstones which impart character to the numerous ridges and isolated hills of Lincolnshire. Altogether, these beds contain an enormous quantity of fossils, most of them in an excellent state of preservation.‡

The nearest equivalents of the Lower Greensand, in the extensive development of the Cretaceous System in America, are the

Fig. 120.—IGUANODON BERNISSARTENSIS.

(From the Skeleton reconstructed and set up by M. J. F. de Pauw in the Brussels Museum.)

* *Neocomian*—or shortly Neocom—is from the Latin name (Neocomum) of the town of Neuchâtel in Switzerland where the lower members of the series are well developed.

† Hence, to avoid the mistakes arising from the name, Mr. Jukes-Browne has proposed to call this formation the Vectian—from *Vecta* or *Vectis*, the Roman name for the Isle of Wight, in which they are well exhibited.

‡ Judd, *Quarterly Journal of the Geological Society*, Vols. XXVI., XXVII., XXIX. etc.

Neocomian beds of the Kootanie country near the Rocky Mountains, and of the Queen Charlotte Islands off the northern coast of

Fig. 121.—RESTORATION OF THE IGUANODON.

British Columbia. Both series contain cycads, pines, and ferns, while those of the Suskwa River and the Queen Charlotte coal beds, which belong to a higher horizon, have in addition a few dicotyledons. In Virginia their equivalent is the Potomac series, while in Greenland the Kome series is seemingly of the same age. In New Zealand their equivalents consist of green crumbling sandstones and conglomerates, in which, on the West Coast, layers of bituminous coal exist. The fossils are essentially marine, though among the plants are species with netted-veined leaves and coniferæ, allied to those still characteristic of the Antipodean flora.*

(*c*) *Gault.*—We now pass into the Upper division of the Cretaceous System,† the distinction being mainly in the rapid change of life in the section we have now reached. Of 300 or more species of fossils found in the Lower Greensand, not over 20 per cent. pass into the Upper Cretaceous. However, there are physical breaks as well. The lithological character of the beds is, as a rule, widely different, while the Gault is frequently unconformable to the Lower Greensand beneath it. The alternations of fresh-water and marine beds of the "Punfield series," just on the upper verge of the Lower Greensand, point to some marked physico-geographical changes being in progress just before the deposition of the Gault. This term is an English provincial one, originally applied to the stiff blue clays, speckled with flakes of mica, and occasionally containing calcareous concretions and septaria, seen at Folkestone and other portions of the south-east coast of England (Fig. 122), where it attains a maximum thickness of 100 feet, and is worked for brick-making. It extends through France to the flanks of the Alps and Bavaria, but in England it nowhere occurs north of Cambridgeshire. Its tough clay beds contain an immense number of fossils, mostly in a fine state of preservation, *Hamites* (Fig. 125, 5), *Scaphites* (Fig. 125, 6), and *Ancyloceras* (Fig. 125, 7), being among the most characteristic of the cephalopods.

(*d*) *Upper Greensand.* — This formation varies in thickness from 3 to 100 feet, though the greensands from which it derives its name are, as in the Lower beds, occasionally wanting. Actually, so far as Great Britain is concerned, the Upper Greensand consists of muds and clays — and sometimes of sandstones — with thin beds or bands of calcareous grit, and an abundance of those phosphatic concretions which render it valuable to the agriculturist.

The *Chloritic Marl*, sometimes classed as a special formation, is a thin bed of very calcareous marl containing the phosphates mentioned, and deriving its colour from the grains of glauconite scattered through it. Like the formation of which it is a member, the Chloritic Marl is confined to the southern districts of England, and follows very closely the range of the Upper Greensand.

(*e*) The *Chalk Marl*, an argillaceous chalk, resting conformably on the Chloritic Marl, and well developed in Folkestone cliffs, and to the thickness of 100 feet in the Isle of Wight, is a better-marked formation. It contains, among other characteristic fossils, *Rhynchonella martini*, *Inoceramus striatus*,

* Hector, *Proceedings of the Royal Society of New South Wales*, 1879, p. 73.

† Some of the German geologists regard the Gault as a Middle Division — represented by their Flammenmergel (a marl)—and by the Aptien and Albien of the French geologists, derived respectively from Apt, a place in the Department of the Basses Alpes, and Alba, the Roman name of the Department of the Aube.

Plocoscyphia meandrina, *Ammonites rothomagensis* (Fig. 125, 10), *A. mantelli*, etc., and probably appears in another form in the shape of the Red Chalk (a hard nodular deposit coloured with iron rust) of one or two places in Yorkshire, Lincolnshire, and Norfolk (Hunstanton). Altogether, the Chalk Marl is about 250 feet thick. It also occurs, with representatives of the Speeton Clay, in Heligoland.

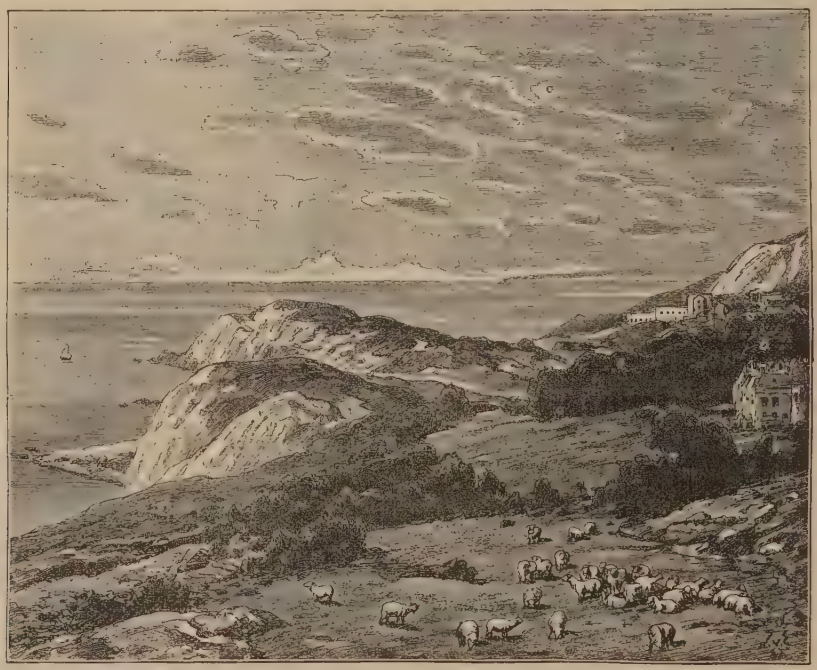


Fig. 122.—DOWNS NEAR VENTNOR, ISLE OF WIGHT (GAULT AND GREENSANDS HERE AND THERE CAPPED BY THE LOWER CHALK).

(*f*) The *Grey Chalk* is sufficiently described by its name. It lies quite conformably on the Chalk Marl beneath it, and, like that formation, is about 250 feet in thickness. It is, however, sometimes mottled and striped, and consists of various "stages," more or less perfectly marked by peculiar assemblages of fossils, each of these assemblages indicating an immense lapse of time, even when the material evidence of these ages does not comprise more than a few feet of chalk.* It is this chalk which forms most of the "White Cliffs" of Kent, though, as the excavations for the Channel Tunnel prove, it extends under the Straits of Dover also.

The arrangement of the beds mentioned is that which prevails in England, and which, for the present, is the most intelligible. On the Continent, however, the Upper Greensand, the Chloritic Marl, the Chalk Marl, and the Grey Chalk, are usually classed as *Cenomanian*.† In Germany the Chalk Marl is represented by the Plänerkalk, a marl, marly sandstone, or limestone.‡ The Upper Greensand is, however, represented by the Unterquadersandstein (Fig. 123) of Saxony and Bohemia. This formation, which weathers into many of the picturesque pinnacles of

* Price, *Quarterly Journal of the Geological Society*, Vol. XXIII., p. 436.

† Shortly, "Cenom," from *Cænomanum*, the Roman name of the town of Le Mans in the department of Sarthe, south-west of Paris.

‡ Sometimes, however, bracketed with the Gault; by other geologists with the Lower White Chalk.

Saxon Switzerland (Fig. 119), so familiar to thousands of holiday tourists, is a glauconite sandstone, which is quarried out in the large squarish or oblong blocks from whence its name is derived.

In America the Cenomanian appears in the Niobrara and Dakota groups, in the Dunvegan series of Peace River in Canada, and in the Amboy clays of New Jersey, as well as in the Grey, it is separated from that formation by a distinct zone, containing *Belemnitella plena*.

However, the present series is also well marked off from that above it by the fact that it seldom, if ever, contains flints, except near the top, and by the summit consisting of a hard yellowish limestone of no great thickness, which is known as the "Chalk

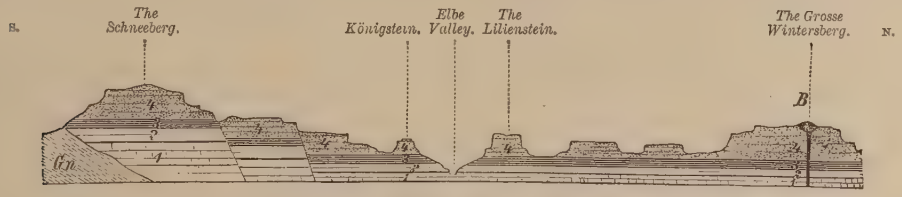


Fig. 123.—SECTION OF THE QUADERSANDSTEIN FORMATION OF SAXON SWITZERLAND.

Gn, Gneiss; 1, The Koricaner Beds (the Lower [Unter] Quader), represented by the sandstone of Klein-Skal, the Muschelfels of Koschitz in the Plauen'schen Grund near Dresden, the Quader of Dippoldiswelda, etc.; 2, The Weissenberger Beds; 3, The Malnicer Beds; 4, The Iser Beds (the Quadersandstein of Saxon and Bohemian Switzerland, the Tetschner Sneeberg, the Adersbacher, and Weckelsdorfer Felslabyrinths of Heuscheur), all belonging to the Middle Quader. [The Upper Quader (Senonian), represented by the Chlomeker Beds, near Jungbunzlau, the Sandstone of Gross Skal, near Turnau, and the sandstone of the Prochover Fels, near Gitschin, is not shown in this section.] B, Basalt.

the Mill Creek Beds of the Rocky Mountains, which contain a great many species of dicotyledons. The numerous fossil plants of the Atane Beds of Greenland (ninety species of dicotyledons having been disinterred from them), which are black shales with dark-coloured sandstones, well exposed at Upernivik and on the Waigat, resemble those of the Dakota and Dunvegan series; while the animal fossils, Dawson thinks, indicate the horizon of Fort Pierre or its lower part.

(*g*) The *Lower White Chalk*.—Hitherto the chalk has been only tentatively present in so far that it has never assumed the form of the white substance containing flints with which every one is more or less familiar. We now come to a deposit which is in England fully 800 feet thick, and in which the lines of stratification are well marked by layers of black flints. It is in other respects a very distinct formation. Between the Lower White Chalk and the Grey Chalk there is a palæontological break. Most of the species are different from those in the beds below, and, apart from the fact that it is believed that in some places, at least, the White Chalk is unconformable to Rock." Occasionally the chalk takes the shape of a hard dull limestone with a splintery fracture, though usually it is the earthy-looking white rock of a texture varying in density, though seldom so firm that it cannot be crumbled by the fingers.

Palæontologically, this division of the chalk can be divided into three zones, each of which has some peculiar fossils, the topmost of all being that of *Holaster planus*, containing layers of black flints. The lowest beds contain comparatively few remains, but the middle one—that of the marine chalk without flints—is full of *Inocerami*, *Terebratulæ*, and other species of molluscs and echinoderms.

The Continental *Turonian** agrees fairly well with the Lower White Chalk, though this also comprises in Germany and France some portions of the inferior formations. The Mittel Quader and the Mittel Pläner of Germany (p. 170) belong to this division. In America we find the Turonian cropping up in the New Jersey marls, the Belly

* From Touraine, an ancient province of France, now comprehended in the Department of Indre-et-Loire.

River group, and the beds of the South Saskatchewan in Canada, with their Sequoias and Brasenias associated with lignites, mined for fuel.

In Greenland, as in the Saskatchewan and Mackenzie, we find red and yellow shales, which "seem to owe their colour to the spontaneous combustion of pyritous lignite," according to Sir William Dawson, though, I confess, I saw nothing there (at Patoot) which would justify this opinion.

(*h*) *Upper White Chalk.*—In physical appearance this division of the chalk does not differ in any respect from that below it, except in the lines of stratification being marked by layers of nodular flints, sometimes of great size (pot-stones), or, rarer, by sheets of flinty matter. Pebbles are also, though very seldom, met with in it, and in one locality (Croydon in Surrey) travelled blocks of considerable size have been found in the chalk. Homogeneous though this chalk appears to be, it has been laid down very slowly, and with considerable pauses between the different depositions. This is seen by the "lithological platforms," characterised by different fossils and texture seen in its mass. One of these is the Broadstairs and St. Margaret's Chalk; another, the Margate Chalk, is characterised by enormous quantities of *Marsupites;* while at the top of the whole is the Norwich Chalk, which is equivalent to the Belemnitella zone of Northern Germany * (Fig. 125, 19).

This chalk is, in England, easily traced from Flamborough Head, in Yorkshire, across the country to the coast of Dorset. "Its western edge," to use Archibald Geikie's language, "usually rising somewhat abruptly from the plains, is a long, winding escarpment, which, from a distance, often reminds one of an old coast line." Actually, however, the white chalk in its various forms ranges from the north of Ireland to the Crimea, a distance of nearly 1,150 miles, and in an opposite direction over the 840 miles between Bordeaux and the south of Sweden, in singular purity, and with a greater uniformity of lithological structure than almost any other stratified rock, with the exception of coal (Fig. 124).

The American equivalents of the Senonian in its lower ranges are the marine series of Fort Pierre, and possibly, though this is still a moot question, the Nanaimo Coal Measures of Vancouver Island, which extend along nearly the entire east and north coast, and crop out on Brown's River, a tributary of the Puntledge, several miles behind the Comox country. These beds contain many dicotyledons, palms, etc., while the upper portion of them may, perhaps, be of a later date. To this series also belong the Fox Hill group of America (marine), the St. Mary River beds, with the Lemna and Pistia beds of the Bad Lands of the 49th parallel (Vol. I., p. 279), the Red Deer River, etc., with lignites, if, indeed, several of them are not, in common with the Patoot series in Greenland, referable to the Danian (or Maestricht Beds).

(*i*) *The Maestricht Beds.*—The Upper White Chalk is the highest member of the Cretaceous System existing within the British Islands. On the Continent, however, there are others of a more recent age, which, from cropping out typically on the banks of the Maas near Maestricht in Holland, have received the name of that town. They consist of a series of yellowish limestones, about three hundred feet in thickness, with a series of fossils, some of which are cretaceous, while others exhibit an approximation to Tertiary remains. Belemnites and Baculites are, for example, mingled with Volutes and Cowries. In France, the Calcaire Pisolitique of Laversine and Mont Aimé and the Calcaire à Baculites of Cotentin belong to this group, while near Mons, and at other places in Belgium, these strata attain considerable thickness. They also exist in the chalk of Saltholm, and at Faxoe in the Danish island of Seeland, where the Faxoe limestone, a yellowish rock forty to fifty feet thick, is extensively quarried for building, and for forming flagstones. These beds lie unconformably upon those beneath, so that, apart from the fact of the fossils in them being different, the Maestricht

* Whitaker, *Memoirs of the Geological Survey*, Vol. IV., p. 46.

Beds are chronologically far apart from the chalk which we have just described. In the Maestricht Beds the head of a lizard, estimated to have been twenty-four feet in length (*Mosasaurus camperi*), has been discovered. But the fossils are mainly *Voluta*, *Cypræa*, *Mitra*, etc., belonging to the Tertiary, and *Belemnitella*, *Hamites*, *Baculites*, *Nerinæa*, and *Scaphites*, belonging to the Cretaceous System. The Faxoe limestone is

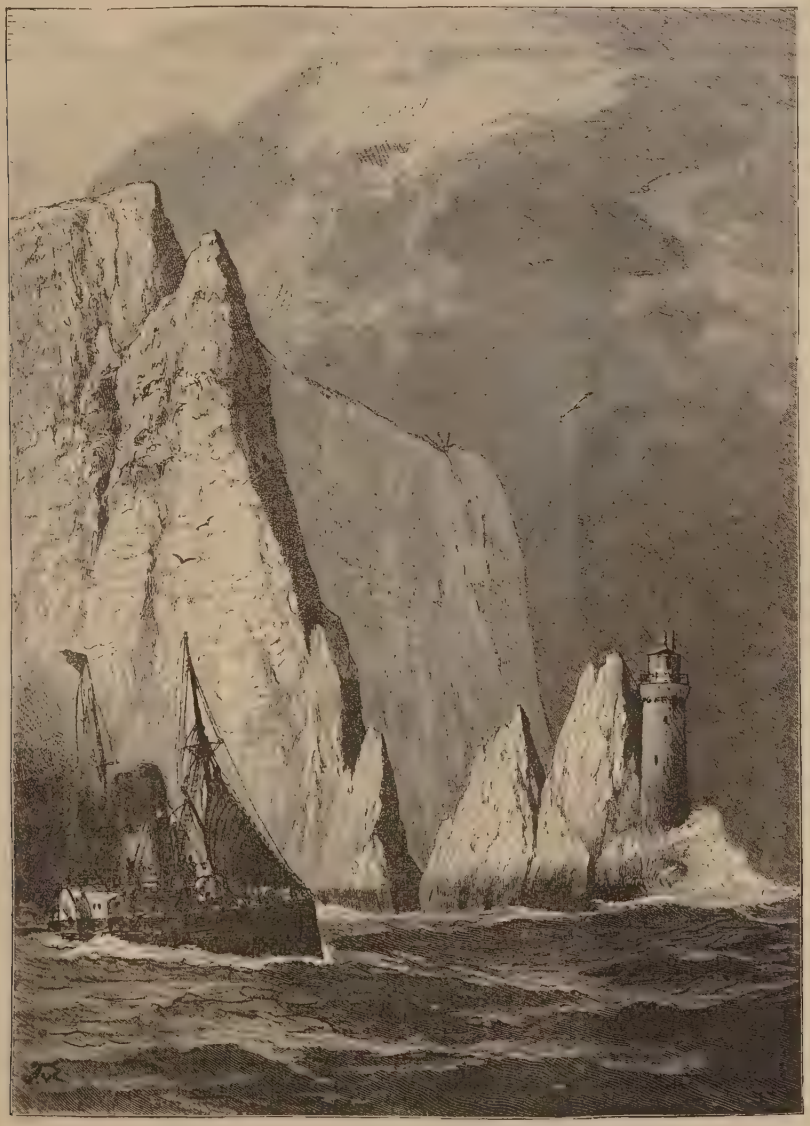


Fig. 124.—CHALK CLIFFS OF THE NEEDLES, ISLE OF WIGHT.

probably a little newer than the Maestricht Beds, usually regarded as its contemporary, though it contains much the same fossils, the most characteristic being perhaps *Nautilus danicus, Baculites faujasi,* and fragments of corals and polyzoa to such an extent as to almost entirely make up the mass of the rock.

With these two exceptions, there is no higher member of the Cretaceous in Europe than the White Chalk, though the suggestion of Edward Forbes, that the Antrim and Norwich chalk might be the representatives of the beds just described, is still tenable, if, indeed, the pisolite limestone in the neighbourhood of Paris, usually classed with the division just described, is not newer still.

The Upper White Chalk is the equivalent of the Continental *Senonian,** while the Faxoe limestone and the Maestricht Beds are the *Danian*† of the French geologists, but the Oberquader (Upper Quader) of Germany may be referred in part to the one, and in part to the other. At one time it was believed that everywhere an immense lapse of time must have marked the close of the Secondary period, signalised by the top of the Cretaceous beds, and the beginning of the Tertiary epoch. There is still in many parts of the world, in England more especially, such a gap. But on the Continent the Danian goes far to fill it up, while in Western America the hiatus scarcely exists at all, a series of beds having been discovered in Utah and Wyoming, which present a thickness of 13,000 feet, and in their alternation of marine, fluviatile, and terrestrial conditions (p. 163), every gradation, from the Cretaceous to the Tertiary. In the highest of these (the Laramie Lignites), which contain numerous coal seams, the mixture of fossils is so puzzling, that it is still an open question whether they are to be referred to the System with which we are at present concerned, or with that which will form the subject of the next chapter. The plants are unquestionably Tertiary, closely allied to the Ounartok beds of Greenland, which at one time—at the time the writer collected the fossils by which Heer made his earliest determinations—were thought to be Miocene, but are now believed to be Eocene, while the vertebrate and other remains are quite as distinctly Cretaceous. We are, therefore, compelled to conclude with Professor Cope, that in this region of the world "a Tertiary flora was contemporary with a Cretaceous fauna, establishing an uninterrupted succession of life across what is generally regarded as one of the greatest breaks in geologic time." Yet, long before the Tertiary formations were deposited on these Laramie beds, they were disturbed, metamorphosed in places into hard slates, and so upturned that the former lie unconformably on them.‡ Altogether, if the Laramie Beds, a very extensive lacustrine or brackish formation, are not to be collated with the Maestricht ones, it seems fitting that they ought to be put into a formation by themselves, which formation, in America at least, forms the link between the Mesozoic and Cainozoic periods. In India also the sequence between the two epochs was partially maintained, and in New Zealand there appears to be no break between the Mesozoic and Cainozoic series of rocks: hence the passage beds are known as Cretaceo-Tertiary. At the base of these beds —from 2,000 to 5,000 feet in thickness—are conglomerates overlaid by coal seams of a poorish quality, while the upper portion comprises the Ototara Stone and the fucoidal Greensands. But as the world in ancient time was characterised by distinct floras and faunas all contemporaneous, just as it is at the present time it is idle to attempt to synchronise with success widely detached formations solely by means of organic remains, even when the strata in question were actually laid

* After the city of Sens in the Department of the Yonne.

† Dania—Denmark.

‡ The age of the Laramie beds has given rise to a voluminous literature and a somewhat acrimonous controversy. The whole question is fully discussed in Mr. Lester Ward's "Synopsis of the Flora of the Laramie Group" (*Report of United States Geological Survey,* 1884–5, pp. 398–557), and by Sir William Dawson in his "Geological History of Plants" (1888), pp. 209, 215, 283, where also the bibliography of the subject is sufficiently particularised.

down at the same period and under the same physical conditions.

Life of the Cretaceous Age. — *Plants.*— With the advent of the Cretaceous Age we notice a remarkable change in the plants and animals; at the same time they bear the impress of the Jurassic flora and fauna far more distinctly than do those of the Eocene strata the impress of Cretaceous flora and fauna. These genera which were plentiful in Jurassic days still survive, though the species by which they are represented are different. Thus we have, among others, *Trigonia* (*Astarte*), *Gervillia*, *Perna*, *Ammonites* (Fig. 125, 10), and *Belemnites* and *Belemnitella* (Fig. 125, 19)—the last three very abundant—with the huge reptiles with which we are already familiar under the names of *Ichthyosaurus*, *Plesiosaurus*, *Ceteosaurus*, and *Megalosaurus*. Nevertheless, it is evident that these are on the wane, and before the advent of Tertiary times they became extinct. In like manner, the cycads, ferns, and conifers, plentiful at the beginning of the Cretaceous Age, have a marked Jurassic facies; but before we ascend far in the series we come upon higher forms than these, though even in the Wealden they were rank enough to form the coal-seams which are mined in strata of that age in North-Western Germany. Plants (many of them trees and shrubs) with netted-veined leaves appear for the first time in the history of our globe, thus showing a distinct advance over anything yet noticed in the vegetable world. What is more, the genera of many of these plants are identical with those now living upon the earth; while some of the species, though not the same as existing forms, are so very closely allied to them that it would seem as if, in the race of life, the plants had approached recent types much more rapidly than the animals. For instance, there are willows (*Salix*), alders (*Alnus*), maples (*Acer*), poplars (*Populus*), oaks (*Quercus*), figs (*Ficus*), screw-pines (*Pandanus*), the beautiful tulip-tree (*Liriodendron*), the magnolia, etc., including representatives of the genera to which the rice-paper plant of China (*Aralia*) and the giant trees of California (*Sequoia*) belong, all in Upper Cretaceous beds in Europe, and, what is still more remarkable, in the Arctic regions, in both localities growing so densely as to have formed seams of coal sufficiently thick to be mined for fuel. In the Cretaceous beds of Aix-la-Chapelle and Westphalia* appear, among some ninety other species of plants, representatives of the order Proteaceæ, which, at the present day, is found only in Australia and the Cape of Good Hope, the very genera being those still living in these countries. This exuberant Cretaceous flora—this extraordinary sudden "inswarming" on the earth of such a host of dicotyledons that in the Cenomanian alone between three and four hundred species have been discovered—was, however, not confined to Europe; it was universal. In the Amboy Clays of New Jersey in the United States (which were nearly contemporary with, or perhaps a little younger than, the Dakota beds of the Upper Missouri) we find many ferns and cycads, conifers, some of which belong to the genera *Pinus*, *Sequoia*, *Thuja*, *Libocedrus*, and *Dammara* (all living genera), magnolias, tulip-trees, aralias, sassafras, cinnamons, ivies, dogwoods, laurels, and a number of other plants closely allied to species now living. Among these are bauhinias, inhabitants mostly of tropical and warm climates, and only one species of which is found in America at the present day. Still more surprising, we find—what is exceedingly rare—flowers belonging to the daisy and dandelion order (Compositæ), while of the species found in the Amboy clays, fully one-third are identical with those disinterred from beds of the same age in Aix-la-Chapelle and Greenland, showing, apart from the facts they indicate regarding a vastly different climate in those days, a distribution of plants with which modern phyto-geography has nothing to compare. In Vancouver Island, on the slopes of the Rocky Mountains, in the treeless soil of the Prairies, and the other localities mentioned, we find a flora equally strange and

* Hosius and von der Marck, *Palæontographica*, Vol. XXVI., p. 125 (On the Westphalian Cretaceous Flora).

equally exuberant. But the most remarkable of all the Cretaceous plant-beds are those to which so much attention has been drawn by the explorations made in Greenland between the latitudes of about 70° and 72°. Here, in sight of eternal ice, in a region where the sea is thick with icebergs, where darkness prevails for a third of the year, are five pines, five Sequoias (the same genus as the "Big Trees" and "Redwoods" of California), two Salisburias, three Baieras, besides beeches, alders, ashes, guelder roses, dogwoods, maples, hawthorns, and other genera of modern character. Altogether, up to the present date 335 species, belonging to sixty families, of which thirty-six are dicotyledons, have been

Fig. 125.—FOSSILS OF THE CRETACEOUS SYSTEM.

LOWER CRETACEOUS: 1, Spatangus (Toxoster complanatus); 2, Rhynchonella depressa; 3, Caprotina ammonia; 4, Aptychus didayi. GAULT (MIDDLE CRETACEOUS OF GERMANY): 5, Hamites attenuatus; 6, Scaphites iwani; 7, Ancyloceras matheronianus; 8, Turrilites bergeri. UPPER CRETACEOUS: 9, Baculites anceps; 10, Ammonites (Acanthoceras) rothomagensis; 11, Inoceramus concentricus; 12, Exogyra columba; 13, Spondylus spinosa; 14, Hippurites cornu vaccinum; 15, Caprina aiguilloni; 16, Terebratula carnea; 17, Actaeonella gigantea; 18, Nerinæa flexuosa; 19, Belemnitella mucronata; 20, Cyclolites elliptica; 21, Ananchytes ovatus (*side view*); 22, Ananchytes ovatus (*from below*); 23, Otodus appendiculatus; 24; Oxyrhina mantelli.

where no plant rises more than a few inches above the ground, and the creeping birch, the crowberry, and the humble arctic willow, are the solitary representatives of wooded plants or shrubs, we find the remains of an exuberant flora (p. 37). Part of this belongs to the Tertiary period, though the greater portion of it must be referred to the Cretaceous System. Ferns, cycads, and conifers are abundant. Among living types, the genera *Populus, Myrica, Quercus, Ficus, Platanus, Sassafras, Laurus, Magnolia,* and *Liriodendron,* are represented, while *Macclintockia* and *Credneria* are among the most characteristic of the extinct genera. There described from the Greenland beds of this age, and no doubt, as the time occupied in their exploration has been short, many more will yet be disinterred from the comparatively small area in which they lie, and where they have escaped the terrible disintegration of that Northern region. This flora is a warm, temperate one, with some admixtures of sub-tropical forms, such as the fig and the cinnamon among exogens, and the genus *Kaidocarpum,* belonging to the Pandaneæ or screw-pines, among a lower division of the vegetable kingdom. In brief, Greenland, during the later Cretaceous period and the earlier Tertiary, was inhabited by plants

which show, in common with the insects found among the vanished vegetation, that its climate was very much what that of California and the Southern United States is at present (Fig. 126).*

But the most suggestive fact about this extraordinary Cretaceous flora is not so much its exuberance—for in earlier times there was even a ranker one,—nor even the changes of climate which it betokens, since all geological history is full of these vicissitudes. What seems to the student of the tale which the Earth has to tell the most remarkable circumstance is, the apparently sudden development of an abundant dicotyledonous flora, composed of plants widely different from those in the immediately preceding Age, and yet not only perfect, but of an organisation which has not advanced in any degree to the present time. The first appearance of plants with netted-veined leaves is in the Cretaceous beds of Kome in Northern Greenland, in the shape of a poplar (*Populus primæva*), and in rocks of much the same age in the Rocky Mountains and in Virginia. Willows, laurels, sassafras, and a few other plants of like rank are found, though rather sparingly. But when we ascend higher up there is a perfect rush of netted-veined forms, such as those we have already mentioned. This fact has staggered even so thoroughgoing an advocate of the Darwinian theory of the higher forms being descended from humbler ancestors as the Marquis De Saporta. He suggests that possibly their evolution may have taken place in some separate region as yet undiscovered, or may have been produced

Fig. 126.—IDEAL LANDSCAPE OF THE CRETACEOUS PERIOD.

* Heer: "Flora fossilis Grönlandica" (1883); "Meddelelser om Grönland," 5te hefte, pp. 43–215; Dawson: "Geological History of Plants," p. 281; Brown: "The Countries of the World," Vol. I., pp. 98–100; and other works referred to in the preceding pages.

by a rapid and unusual multiplication of flower-haunting insects. The truth is that this phenomenon is still one of the many mysteries of Geology which Time alone can solve. In any case, "whichever hypothesis one may prefer, the fact of the rapid multiplication of dicotyledons, and of their simultaneous appearance in a great number of places in the Northern hemisphere at the beginning of the Cenomanian epoch, cannot be disputed."*

Some of the plants mentioned are so closely allied to living species, that it is sometimes puzzling to say wherein the distinction lies. Indeed, did we not know that it is vain to look for forms of Cretaceous times identical with those of our day, the slight difference between the two might be overlooked. The Salisburia or Gingko tree of China (p. 104), which was represented by certain forms in preceding ages, ranged during the Cretaceous Period as far north as Siberia and Greenland, and the Sequoias—the genus to which the red wood† and the so-called Wellingtonia‡ of California—belong (though nowadays found nowhere else) were, from the Lower Cretaceous age onward, represented by numerous species in almost every region of the Northern hemisphere, and even in the Eocene of Australia. The genus thus spread in Tertiary and Cretaceous times from the Arctic to the Antipodean regions, in the shape of twenty-six species, fourteen of which were natives of lands now treeless under a Polar sky. In America, curiously enough, a genus now so extremely circumscribed in its distribution as the Sequoia, was, in earlier ages of the earth, so widespread in America that, as Sir W. Dawson has shown, much of the material of the great lignite beds of the Canadian North-West consists of wood of both the modern species.§

Animals.—Exuberant as are the plants of the Cretaceous Period, the marine beds of the system are scarcely less full of the remains of animals. Foraminifera are especially abundant, the chalk rock being to a large extent composed of these minute delicately-shaped shells, while the glauconite grains which impart their characteristic colour to the greensands are, in many instances, the internal casts of these creatures' tests. The general characteristics of chalk have already been discussed (Vol. I., pp. 55, 74), and in Figs. 127–130 are shown fragments of it, highly

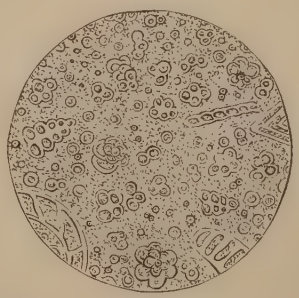


Fig. 127.—THIN SLICE OF WHITE CHALK (SURREY) AS SEEN UNDER THE MICROSCOPE, SHOWING THAT THE ROCK IS COMPOSED OF MINUTE SHELLS (*Foraminifera*) EMBEDDED IN A GRANULAR BASIS OF LIME.

magnified,—diagrams which may be compared with that of a fragment of Meudon chalk in Vol. I., p. 352. From this it will be seen that though we are not "living in the Cretaceous Period," as Sir Wyville Thomson, from mistaking the exact analogies between ancient chalk and modern sea-ooze, was at one time fond of insisting—the deposit at present forming in the great oceans from the remains of foraminifera affords us some inkling of the source whence these vast accumulations of chalk were derived. Several of the genera of foraminifera found in it are, indeed, identical with those composing the mass of chalk. Among these *Globigerina*, which so largely enters into the composition of the Globigerina Ooze, is a notable example in point (p. 4 and Fig. 12, Vol. I.). At the same time they do not make up more than one half of the rock, the rest being composed of various other organic fragments, so

* Saporta: "Monde des Plantes," p. 197.

† *Sequoia sempervirens.*

‡ *Sequoia* (*Wellingtonia*) *gigantea.*

§ Dawson, *Transactions of the Royal Society of Canada*, Vol. II., Sec. IV. (1885), pp. 1–22; Gray, *Annals of Natural History*, Vol. II. (4th Series), pp. 52–70, and Heer's works generally, for the history of this remarkable genus of plants.

that it is not quite accurate to completely identify the Chalk with any modern formation, though not a doubt need exist that the general mode in which it was laid down was closely akin to that in operation so far as the ocean oozes are concerned. The "Red Chalk" of Norfolk and Yorkshire derives its colour from containing about four per cent. of oxide of iron,* so that, the manganese aside, it may be compared with the red clay which forms so remarkable a feature on the bottom of some seas (Vol. I., p. 35). Some of the red chalk, also, when treated with acids, leaves behind an argillaceous residue, which consists of ferric oxide (oxide of iron), alumina, and a small amount of magnesia and potash, while most of the varieties contain silica,† so that it is scarcely chalk at all.‡ The old Cretaceous seas swarmed with sponges, as is proved by the multitude of their spiculæ or skeletons found in the Chalk (Fig. 132), and the numerous species of these lowly animals exhumed in a more or less perfect condition. At one time the flints which form so characteristic a feature in the Upper Chalk strata were believed to be sponges, round which, as round a nucleus, the free soluble silica of the Cretaceous seas had gathered. This doctrine is not now so generally held, though unquestionably in the interior of many flints sponges are found, but sea-urchins, shells, corals, and other organic substances, are also seen in these positions, often with the original calcareous matter replaced by silica. The lines which the flints occupy in the Chalk beds render it almost certain that before the silica had begun to be eliminated, or segregated from the Chalk seas by means of these organisms acting as nuclei, the ooze of which the Chalk is composed had been largely deposited. It may be mentioned that flints are not confined to the Chalk, but are seen in the mountain limestone and the Oolite at some places, while in certain localities —in the Chalk of Ireland, for example— the silicious matter (which in most cases takes the form of nodules) is arranged in extensive sheets, a peculiarity which also holds good in some portions of the white limestone of the Mediterranean shores. From the fragments picked up in Seeland these sheets appear to have occurred in conjunction with ordinary flints in the denuded Cretaceous beds of Denmark. Such sheets of silica have either been deposited from the sea in which it has been held, or they have filled shrinkage cracks in the old sea bottoms. At Rottingdean on the Sussex coast the latter arrangement is well exhibited, while in other places, at Leatherhead in Surrey, for example, the nodules of flint would appear to have become cemented together so as to form tabular horizontal masses.

Fig. 128.—CHALK OF GRAVESEND. (*After Ehrenberg.*)

A still more peculiar arrangement is seen in various parts of England, at Horstead, near Norwich, or on the beach near Cromer, for instance, where a number of large pear-shaped flints, from one to five feet in height and from one to two feet in diameter, are piled

* Clapham, *Chemical News*, Vol. VI., p. 313.

† Church, *Chemical News*, Vol. XXXI., p. 199.

‡ Wiltshire (*Quarterly Journal of the Geological Society*, Vol. XXV., p. 185) regards the Hunstanton beds as homotaxial with the Upper Gault of Folkestone.

end to end until the vertical piles stand like so many pillars at right angles to the line of bedding in the chalk rock. These flints, known from their distant resemblance to that utensil, have received the name of "pot stones," though for the present no satisfactory explanation of their origin has been given. It seems, however, that in some way they are connected with the growth of ancient silicious sponges, in successive generations, one above another, in much the same manner as the modern *Holtenia* lives.

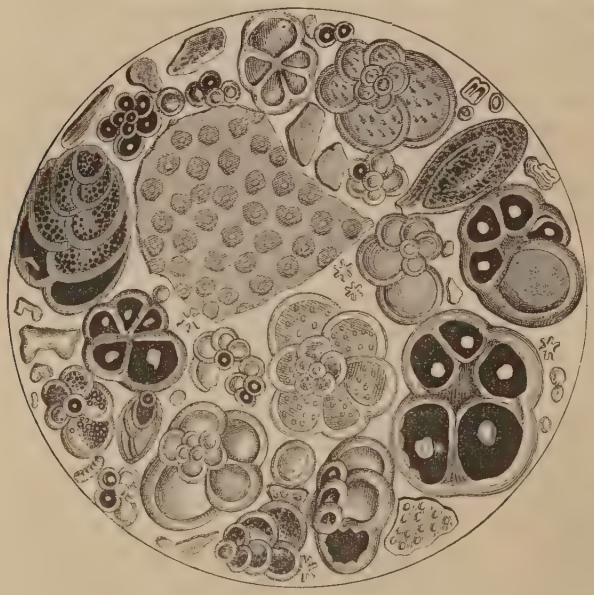


Fig. 129.—CHALK OF CATTOLICA, SOUTHERN SICILY.

Sponges, at all events, were abundant in the Cretaceous seas, and that the accumulation of silica round them and other nuclei was accomplished in much the same manner as we have indicated, is rendered probable by the fact that the Upper Chalk of Yorkshire, which does not contain any flints, holds twice the amount of silica which analysis has detected in the Middle Chalk, noted for its abundance of these nodules. The "Sponge gravels," as the beds to the south of Faringdon are called, are full of fragments of these organisms, as well as of sea-urchins, molluscs, and other hard-cased animals. Sea-urchins, in especial, were very numerous (Fig. 125), while corals were in places so abundant as to constitute regular reefs, which may be regarded as the real character of the Faxoe limestone of Denmark. Brachiopods, though not so plentiful as in former ages, were still present in such genera as *Terebratula* (Fig. 125, 16) and *Rhynchonella* (Fig. 125, 2), both of which are represented in modern seas, but not by the same species as in Cretaceous times; while the group of mollusca proper, known as Lamellibranchiates — two-valved forms — were more abundant than in any immediately preceding period. *Inoceramus* (Fig. 125, 11) is another characteristic genus, and the family of Hippuritids, which comprises a variety of eccentric bivalves, living attached and associated in beds like oysters, was not only numerously represented, but peculiar to this System (Fig. 125, 14). Those best known belong to the genera *Hippurites*, *Radiolites*, *Sphærulites*, and *Caprina*, and in some beds of the south of Europe, from France through the Alps into Dalmatia, and around the Mediterranean Basin into Asia, they are so thick as to form the "Hippurite limestones," which, from the relative abundance of particular species, are variously known as Rudistenkalk, Caprotinenkalk, etc.; just as others, for a like reason, have been named by the Alpine geologists, Spatangenkalk, Bryozoenkalk, Orbitolitenkalk, Aptychenkalk, etc.

Cephalopods were still familiar animals, both in their naked and shelled types. The latter took very strange shapes, for, besides the sober-fashioned *Nautilus*, there was *Crioceras*, with the coils of the shell not contiguous, like the coil in a ram's horn; *Scaphites* (Fig. 125, 6) and *Ancyloceras* (Fig. 125, 7), in which one end was curled up like a crozier or an expanding fern; *Hamites*, as its name signifies, bent hook-like upon itself (Fig. 125, 5), *Turrilites*, a spirally-coiled form (Fig. 125, 8),

besides the more ordinary *Ammonites* (Fig. 125, 10), *Belemnites*, and *Baculites* (Fig. 125, 9), a genus living in straight chambered shells. Altogether, there seems to have been a flush of cephalopods of this character just before the Order disappeared; for none of them survive the Upper Cretaceous Period, so far as Europe is concerned, though the Ammonites lingered on, in the American continent, during the interval between the deposition of the Cretaceous and the beginning of the Tertiary (a pause less marked in the New World than in the Old), since they survive in the oldest Tertiary beds of California. And here it may be remarked that, as we approach our own times, the distribution of species seems to get more circumscribed than in earlier days. For instance, the Hippuritids, so abundant in the strata of the south of Europe, are found very sparsely in those of the north, as if only scattered forms, which had wandered to the outskirts of their range, had existed at that period; while the Cephalopods, abundant as they are in the area comprising England, France, and the region to the eastward, were by no means frequent in the more southern region. The crabs, lobsters, and water-fleas of the Cretaceous seas were less remarkable. Yet in the forms then present we begin to observe the semblance of their modern descendants, bizarre and unclassable types being no longer among the species which are dug out of the rocks.

The families of fishes so frequently found in the Jurassic beds are still present, though in different forms; and now for the first time we find species which belong to the same group as the herring, the cod, the salmon, the perch, and the flounder. These "Teleostei"—to which are assigned the greater number of modern fishes—have skeletons usually bony throughout and equally-lobed tails, though as yet none of the genera *Osmeroides*, *Beryx* (Fig. 131), *Enchodus*, etc., have any modern representatives. The Ganoids are here also, though no longer of special importance, and the number of sharks' teeth (Fig 125, 23, and 125, 24) scattered through the Chalk shows that these ravenous fishes held their own in those times quite as firmly as they did in the ages preceding and succeeding the Cretaceous Period. The Cestracionts are represented by a new genus peculiar to the Cretaceous (*Pycnodus*), though one or two old ones still survive.

The reptiles of the Wealden we have already

Fig. 130.—MICROSCOPIC FOSSILS IN A PIECE OF WHITE CHALK.

1, Globigerina; 2, Nodosaria; 3, Rotalia; 4, Coccoliths; 5, Sponge spicules.

noticed. Those found in the higher beds, classed as Cretaceous, are not so numerous or so well preserved as in the lower members of the series. Of these the most remarkable are found in the beds of America. Here the species are entirely different from the European forms, though their resemblance is sufficient to betoken a near relationship to some of those disinterred from rocks on the latter continent. One of them, *Lælaps*, resembled *Megalosaurus*, while *Hadrosaurus* was more akin to the *Iguanodon*. There are also many species of *Mosasaurus*—one seventy-five to eighty feet long—all distinguished by their long serpent-like bodies, and teeth, like those of snakes, on the roof of the mouth, so that they could seize their prey with greater ease. Another point which brings these *Pythonomorpha*, or snake-like brutes, as Cope has called them, still more

closely to the serpents is the fact that, by each half of the lower jaw being jointed nearly midway between the ear and the chin, these animals could, like modern snakes, swallow their prey entire. Altogether, over fifty species of Pythonomorpha are known—a remarkable fact, no matter whether we accept Cope's view of their affinity, or Owen's,

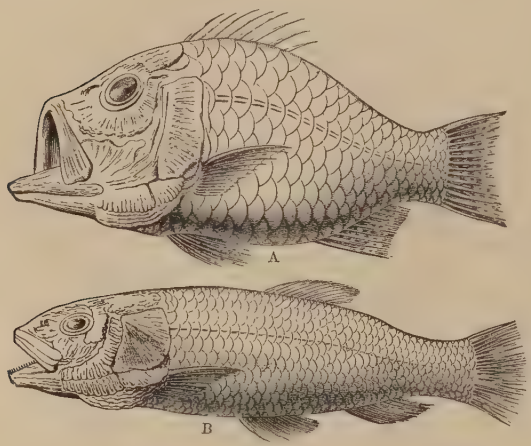


Fig. 131.—FISHES OF THE CRETACEOUS PERIOD.

A, Beryx lewesiensis; B, Osmeroides mantelli

that they were more closely akin to the lizards. *Discosaurus* was another amazing reptile, forty feet long, with a Plesiosaurus-like neck rising twenty feet out of the water. From the structure of its body, Cope * infers that it "probably swam many feet below the surface, raising the head to the distant air for a breath, and then withdrawing it and exploring the depths forty feet below without altering the position of its body. It must have wandered far from land; and that many kinds of fishes formed its food is shown by the teeth and scales found in the position of its stomach." Pterosaurs were also frequent in Cretaceous America, some of those described by Marsh being notable by the absence of teeth and a wing-spread of from twenty to twenty-five feet—larger than that of any European pterodactyle.† Fourteen crocodiles, thirteen sea-lizards, and forty-eight turtles and tortoises are among the other spoils discovered in the Cretaceous rocks of Western America. One of the latter must have measured nearly fifteen feet between the flippers. Altogether, the Cretaceous Period was still more worthy of being called the Age of Reptiles than even the Jurassic, since, both in number and in species, the one period can fully compare with the other.

In the Cambridge Greensand bones of what seem two species of *Enaliornis*—swimming or wading birds—have been discovered, though, so far as we are able to judge from the fragments found, the reptilian taint had not got entirely eliminated from the structure of these ancient grebes or penguins. These, up to the date of writing, are the only Cretaceous birds found in Europe. But in America—in the Upper Cretaceous of Kansas—Marsh has found (in the same prolific Western deposits which have yielded so many other treasures to Science) two types of toothed birds, species, therefore, akin to, though not so reptilian as, the Archæopteryx. One of these (*Hesperornis regalis*) had a decidedly reptilian type of brain, though otherwise more bird than lizard, with habits allied to those of the loon, though incapable of flight. In general terms, it may be described as a carnivorous ostrich, which frequented the water rather than the land. It may possibly, like the Archæopteryx, have had a reptilian tail, though Professor Marsh favours the belief that this consisted of straight feathers, capable, like the beaver's tail, of assisting its motion through the water. That it was a fish-eater is certain, and, from its powerful frame, it could no doubt lord it freely among the few members of its order when the Rocky Mountains were only islands rising in the midst of a semi-tropical sea. "The surrounding circumstances," Professor

* "U.S. Geological and Geographical Survey of the Territories," 1875; Geikie's "Text Book," p. 817, from which this reference is taken.

† Marsh, *American Journal of Science*, from 1871 to 1884 (Vols. I., III., XI., XII., XXI., XXVII.).

Marsh tells us, "were evidently favourable to *Hesperornis* for a long period. There was, apparently, during this time an absence of enemies in the air above, and an abundance of food in the water. *Hesperornis* was more than a match for the gigantic toothless pterodactyles which hovered over the waters in such great numbers (p. 182), and the other inhabitants of the air all appear to have been small. The ocean in which *Hesperornis* swam teemed with fishes of many kinds, and thus a great variety of food was at hand, and was obtained with little effort. In this aquatic paradise *Hesperornis* flourished, disturbed only by the serpentine Mosasaur (p. 181), which, even without tradition, we may imagine, caused its banishment, if not its destruction." If Professor Marsh's estimate, that from the bill to the toes it measured between four and six feet, is correct, this gigantic Diver was larger than any known aquatic bird.

Ichthyornis victor, another American Cretaceous bird, derives its generic name from the circumstance that its vertebræ are bi-concave like those of fishes, but in other respects it was, though much smaller, more developed than *Hesperornis*. It had wings well fitted for flight, and a breast-bone so prominently keeled, that it is clear these wings must have been moved by powerful muscles, though the teeth, placed in sockets and reproduced just as those of crocodiles are (those of *Hesperornis* being in a common groove as in *Ichthyosaurus*), with the reptilian skull and backbone still more lowly organised, hint at the rest of the "fish-bird's" organisation not having kept pace in advancement with the portions fitting it for flight. In brief, just as the Hesperornis was a loon, so the Ichthyornis may be compared to a tern, which skimmed along the marshes and seashore intent on fishing. *Apatornis*, *Baptornis*, *Graculavus*, *Laornis*, *Palæotringa*, and *Telmatornis*, were other genera of American Cretaceous birds, having much the same general characters as *Ichthyornis*. Some of those discovered in the Cretaceous beds of the Atlantic coast, and especially in the Greensand region of New Jersey, are in the shape of isolated bones, so that it is difficult to decide positively whether the birds to which they belonged possessed teeth, though the probability is in favour of this inference from the rest of their structure. The toothed species described are all from the eastern slope of the Rocky Mountains, and especially from the adjoining plains of Kansas and Colorado, which belong to the Middle Cretaceous, where they are associated with Mosasaurs, Plesiosaurs, Pterodactyles, and many fishes, in addition to Ammonites, Belemnites, and other Cretaceous invertebrates.* Mammals, there can scarcely be a doubt, existed during the Cretaceous Period. Yet up to the present date no trace of them have been found in any rocks of that age.

Physical Features of the Cretaceous Period.—The Wealden is a formation so characteristic that we have no difficulty in gathering from the nature of this deposit and the plants and animals contained in it, that at the close of the Purbeck, the marine conditions which prevailed over a large area of Europe, and especially of the south of England, gave place to others of a different character. The sea bottom seems to have been elevated, and a river, or series of rivers, to have deposited above the Purbeck accumulations the mud brought down by them in the shape of a vast delta. At the same time, though the physical conditions of the country altered, there was, at least so far as the south of England is concerned, no break in the continuity of life, for the Wealden lies conformably to the Purbeck below. The type, however, of life was altering, new forms taking the place of the old ones, the banks of the rivers forming the delta being clothed with ferns, cycads, and conifers, while reptiles of the species already described (p. 167) haunted its shores, and sharks and ganoids swarmed in its waters. Marine conditions, however, prevailed in the south, so that while the Cretaceous system is in England divisible

* Marsh: "Odontornithes: A Monograph of the Extinct Toothed Birds of America" (1880); "Birds with Teeth" (*U.S. Geological Survey*, 1881–2, pp. 45–88), and Dr. Shufeldt's paper already noted.

into a lower or fresh-water series and an upper or marine division, this rough classification does not quite hold good all over the world. During the Wealden Period much of England and Scotland must have been dry land. Wales stood in the middle of it, and nearly all of Ireland, most probably during this age of the earth, was above the water. The British Isles, it is perhaps needless remarking, water beds around the Oolitic and Purbeck strata, and by such phenomena as the occurrence of Pterodactyles, and the long-tailed *Archæopteryx macrura* in the Solnhofen slate of Bavaria."

How long the Wealden took to accumulate we cannot guess with anything like accuracy. But it is certain that before the overlying marine beds were deposited, the country in

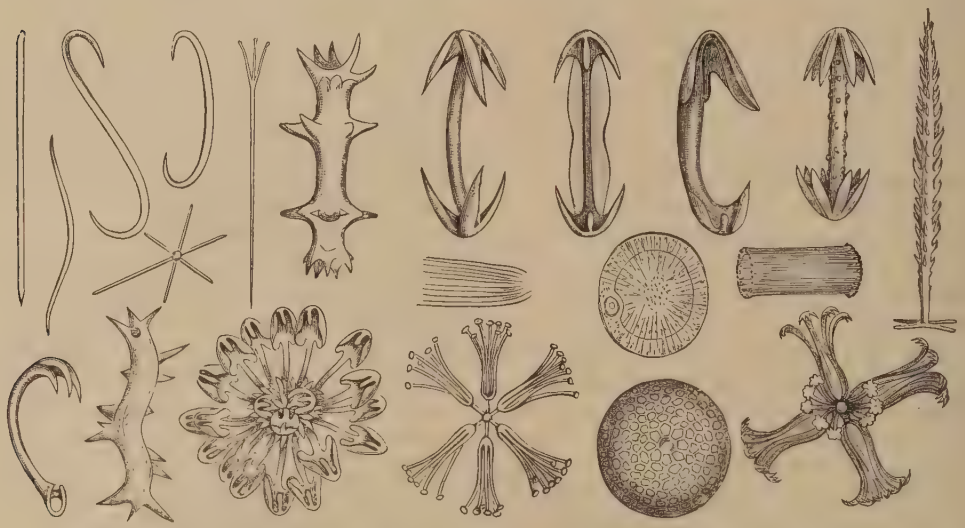


Fig. 132.—VARIOUS FORMS OF SPONGE SPICULES. (*After Bowerbank, Schmidt, Sollas, etc.*)

did not exist as islands for long after this period. They were part of the Continent. "Of this, however, we are sure," Sir Andrew Ramsay writes, "that the Scandinavian Mountains were then loftier than at present, for they are certainly of older date than the deposition of the Old Red Sandstone, and probably older than the Upper Silurian series, and have suffered degradation ever since; that the chain of the Ural was in existence, for it is of older date than the Permian strata; that the mountains of the Schwarzwald then rose high in the air, for they are older than the New Red Sandstone; but the Alps, the Pyrenees, and some other mountain chains, if they existed at all, were in the rudimentary stage of comparatively low lands, feebly indicated by the occasional occurrence of fresh-

which they lie was submerged, and that this submergence extended over the breadth of Europe, and was deepest where the great accumulations of Chalk are found. Farther south and east the sea was shallower, and it has been inferred from various facts that the Mediterranean of Cretaceous times was a broader sea, so far as Europe was concerned, and stretched so far over Asia that it communicated with the Indian Ocean. The Chalk beds must have taken an even greater time to form, for if the deposition of the Atlantic and other deep sea oozes is to be accepted as any criterion, this process is so slow that no more than a foot forms in a hundred years. Now, as there are beds of Chalk fully 800 or 1,000 feet thick, the years occupied in their accumulation may be imagined. However, as

already indicated, though the oozes of modern seas may be regarded as the analogues of the ancient chalk, it is affirming too much to infer, in the present state of our knowledge, that the two are identical. Indeed, so far from it presents many points of analogy to the Calcareous ooze, there are none of identity. In his opinion, it stands alone amongst British strata in its peculiar structure and origin. He will even go so far as to hazard

Fig. 133.—PALMS OF THE CRETACEOUS PERIOD (RESTORED).

looking to the one as the homologue of the other, Mr. Prestwich—a distinguished geologist, who still eyes with scepticism the now almost universally accepted doctrines of uniformitarianism (p. 3)—contends that the conditions under which the Chalk was deposited were peculiar and special; and that, though the belief that the Chalk, unlike the ooze, was not of slow growth, and as it contains much free calcareous matter, in addition to the foraminifera, etc., described, he is inclined to believe that, in addition to the accumulation of this organic calcareous *débris*, there was at that time a "considerable chemical precipitate

of carbonate of lime taking place in the Chalk sea," a condition of matters, we may take leave to observe, not quite compatible with the existence of animals to whom clear water is essential. It has been inferred, from the presence in it of genera of foraminifera, etc., which do not affect very deep water, that the Chalk was a comparatively shallow water deposit, formed at a depth of from 1,000 to 2,000 feet. On the other hand, the sponges which it contains, and its remarkable purity and freedom from shore refuse, would indicate a state of matters somewhat different.* Altogether, after weighing the facts *pro* and *con.*, the reader may perhaps come to the conclusion that there is about as much to be said for the one contention as for the other, and that it is less difficult to reconcile the points of difference between the Ooze and the Chalk, than to accept the theory of the ancient seas having been subjected to conditions so extraordinary as those suggested. During the whole of the Cretaceous Period there must have been many oscillations of the land. These are easier to follow in the Lower members of the series than in those of the Upper division, owing to the varied character of the strata composing the first-named group. But even during the deposition of the Chalk, the researches of Barrois and others have left no doubt that there were many such changes. The shingle beds of the old shores, and the eroded surface of the Chalk at different stages, accompanied with marked palæontological changes, prove this. One of the most positive of these is that which exists between the Turonian and Senonian stages, for, though there is no decided beach line, the underlying beds are broken up, the fragments rolled, rendered phosphatic, and, Mr. Prestwich tells us, near Lille, covered with serpulæ and oysters; while in the neighbourhood of Amiens the surface of the underlying zone is largely eroded and pierced by boring molluscs. At the end of the Senonian Period the whole of the Chalk sea underwent a rise, and, just before the Danian stage, there was another break, accompanied by a great erosion of the surface; a beach line of that period remains in the form of the pebble bed of Malogne.†

The plants and animals of the Cretaceous indicate a warmish climate (Fig. 133), while the occurrence of shrubs at present only represented in the latitudes of California and the Southern States of America points to the now frigid region of Greenland having, during the later stages of the Period, been widely different in its climatic conditions. Erratic blocks in the Cambridge Greensand have been held to prove the presence of floating ice in the Cretaceous seas. These "erratics" may, however, have been due to other agencies. At Purley, near Croydon, they consisted of a block of decayed granite and some quartzose sand. Between Canterbury and Dover a piece of coal was met with, while it is not uncommon to find rolled fragments of white quartz in the Chalk, and in the coprolite beds of Cambridgeshire pebbles and small boulders of felspathic and palæozoic rock are occasionally seen. These may have been derived from adjacent land, though, as the ancient reptiles (like the crocodiles of the present day) might have cherished the habit of swallowing such pebbles, it is not improbable that some of those mentioned had a different origin. Some of them might even have been dropped from the entangled roots of floating trees. It is, however, more than probable that not only were there many vicissitudes of climate during the long Cretaceous Period, but that then, as now, different regions had different atmospheric peculiarities. Palæontologically these regions certainly existed. Even in France there is a notable difference between the deposits of the North and South of that country. In the one area they are part of England, while the South is linked with the Mediterranean region. In short, Cretaceous France partakes, in some respects, of the characteristics of the modern country in its ethnological aspects. There have, so far as Europe is concerned, been several such provinces marked out. These, according to Gümbel, are:—(1), The Northern and North-

* Prestwich: "Geology" (1887), Vol. II., pp. 313–328.

† Prestwich: "Geology," Vol. II., pp. 315–317; Barrois, *Ann. Soc. Géol. du Nord*, Vol. V., p. 227.

Western Province, comprising Belgium and Holland, Russia, Aix-la-Chapelle, Westphalia, the Teutoburger Wald, Hanover, Brunswick, Lüneburg, the northern flank of the Harz, the Isles of Rügen and Wollin, the Danish Isles and the southern part of Sweden, and westerly to Northern France and Great Britain; (2), the Hercynian Province, comprising Saxony, Bohemia, Lower Silesia, and Moravia in the vicinity of Regensburg (Fig. 123)—this is the region of the Mid-German Quadersandstein; (3), the Southern Province, comprising Portugal, and across the Pyrenees into Southern France and the Alpine slopes, its most marked fossils being Hippuritids; (4), the Eastern Province, comprising Upper Silesia, the Northern Carpathians and Poland, the Balkan Peninsula, etc.

Scenic and Economic Aspects of the Cretaceous System.—The Cretaceous rocks are not greatly disturbed by volcanic outbursts. However, those of the North of Ireland and the West of Scotland are overlaid by great sheets of basalt dating from the Tertiary Period. Of this outburst the Giant's Causeway is a notable remnant. In America the Laramie Beds have been so disturbed by intrusive outbursts, that in places these lacustrine sandstones and clays have been metamorphosed until they look more like Palæozoic slates than the unaltered strata to which they belong. In Western America also the Cretaceous beds have been frequently upheaved and intersected by traps. In Vancouver Island, for example, there is evidence of various dykes penetrating the Cretaceous coal-beds of Koskeemo Sound on the north-west coast of that island, and the elevation of the northern part of the Cascade Mountains is attributed by Dr. George Dawson to post-Cretaceous times.*

In the Pyrenees and Alps also the Cretaceous strata are much disturbed, and in the Carpathians, in Moravia, and Silesia, there are many outbursts of basalt and of other eruptive rocks, particularly of the one locally known as "teschenite," a diabase or doleritic material. But it is in India where the most remarkable outpouring of contemporary basalt occurs. In the Deccan Cretaceous these sheets attain a thickness of from 4,000 to 6,000 feet, and at places an even greater thickness, over an area of some 200,000 square miles, being in many instances regularly interstratified with the uppermost members of the Cretaceous rocks with which they mingle.†

In England, however, though the Cretaceous strata are broken by faults, they are not disturbed by intrusive outbursts from below. Hence, the scenery of the Chalk districts in this country is seldom bold, and, unless where the rocks are weathered into fantastic shapes, not so picturesque as in the Quadersandstein districts of Saxon Switzerland (Fig. 119). The rounded hills and smoothly hollowed out valleys of the wolds and downs of the counties in the vicinity of London—such as Kent, Sussex, Surrey, Hampshire, Wiltshire, and Berkshire—are good types of the ordinary peaceful scenery of this system (Fig. 134). The Chalk hills, with their unbroken outline and short nutritious herbage so admirably fitted for rearing certain breeds of sheep, form characteristic features of the scenery of England from Dorchester to the Norfolk coast, where the Wash intervenes between them and Lincolnshire, from whence they continue with little interruption to the Humber. In Yorkshire they form the Wolds, and the cliffs of Flamborough Head are of chalk. Salisbury Plain is an undulating tract of the same stratum, and both the North and South Downs—the one terminating in Beachy Head (Fig. 135), the other in the Forelands and Dover—are wavy expanses of chalk, while other less notable ridges or outlines are found in Devonshire, the Isle of Wight, and other regions of England. Tame and monotonous though the scenery of the Chalk usually is, it possesses "a prettiness all its own" with its "endless succession of soft and gently undulating heights, bare above and partly clothed below with scattered patches of woodland," as in the Wolds and Downs. Where it forms cliffs, the scenery is much grander, as every one who has seen the noble rocks off the south side of Filey Bay, near Flamborough Head (Fig. 137), and

* Willis, *Science*, Vol. XI. (No. 266), p. 122.

† Medlicott and Blanford: "Geology of India," p. 241.

Beachy Head (Fig. 135) with its bold front, the jagged stacks of the Needles (Fig. 124), or the dizzy mass of Shakespeare's Cliff near Dover—the "white cliffs of Albion"—must be aware.* In Lincolnshire—near the village of Tealby, for example—where the ferruginous sandstones, sandy clay, and limestones, are cut loops and links among the dales," as in the front of the Marlborough and Lambourn Downs on one side of the Thames Valley, and the Chiltern Hills on the other; the hardness of the chalk in these places preventing the erosion which has rounded away the rock in other localities.

Fig. 134.—CHALK DOWNS NEAR CLANFIELD, HAMPSHIRE.

through by the streams flowing to the westward, they appear like spurs standing prominently at right angles to the chalk Wolds, the terraced appearance of these spurs being—as Mr. Tate has pointed out—in striking contrast to the smoothly rounded undulations of the latter. Sometimes, when the chalk forms escarpments overlooking the Wealden, the face of these cliffs is sufficiently abrupt to break the monotony of the "long backs of the bushless downs," with their faintly shadowed tracks winding "in

* *See* Professor Lapworth's "A Piece of Chalk" in *Science for All*, Vol. V., pp. 65–72.

The economic purposes to which the constituents of the Cretaceous System are applied are more varied than important. Its soil is not, as a rule, rich, though as pasture lands the Downs have long been famous. For this reason, perhaps, Sir Andrew Ramsay, formerly Director-General of the Geological Survey, suggests that, where the country is high and the Chalk only a few inches under the surface, much of the Downs until recently lay uncultivated. Railways, a more dense population, and high farming, have, however, gradually brought the best parts of them under the plough, though, during the period

of agricultural depression which began about 1876, many of the worst parts went out of tillage. Salisbury Plain is no longer the pathless waste on which the bustard roamed free, and where Mr. Pepys and party lost themselves two centuries ago. It is even ceasing to be monopolised by sheep. This

Sands form on the surface a fine, dry, sandy loam; but the Lower Greensand being excessively silicious, mingled here and there with strings and veins of sandy oxide of iron, with little lime, is so barren and untractable, that much of the country covered by it is still in a state of nature, very pleasing to

Fig. 135.—CHALK CLIFFS OF BEACHY HEAD.

chalk soil, however, unless well qualified by vegetable mould, is stiff and cold, and in most places has been left for commons, furze patches, and woods, or is devoted to brick-making. Deep drainage has rendered the naturally stiff damp soil of the Wealden reasonably fertile, and when topped by deep beds of superficial loam—as in parts of Sussex and Kent—is famous for the hops and cherries grown on it, as well as for the brick-works which, as at Sittingbourne, have been established in such spots. The Hastings

the artistic eye, and to the lover of rural England, but distressing to the exponent of the doctrine of how every rood should support its man without Nature being consulted in the matter. The valleys are more fertile, and here farms, woods, and parks, diversify the landscape. The Gault, unless covered by drift or alluvium, is usually a wet soil*—low-lying and full of springs, so that it is better to live on its border than on the Formation itself.

* Ramsay: "Physical Geology and Geography of Great Britain," pp. 572–575.

The Gault is, however, in favour with brick-makers, the tenacity of its dark-grey, blue, or brown clays being equal to those of the Eocene deposits, so familiar to residents in the Thames Valley. The phosphatic nodules, found so frequently in some members of the Cretaceous System, are extensively worked for the manufacture of manure. In the Gault and Upper Greensand at Farnham in Surrey there is a brisk trade in these nodules, most of which are coprolitic (Vol. I., p. 56). The New Jersey "Marls" or Greensands are extensively used for similar purposes, their fertilising properties, however, being due to a percentage of phosphate of lime much smaller than in the English beds.

Fuller's-earth has been found plentifully in the Lower Greensand of Nutfield near Reigate, and at Woburn in Bedfordshire, in a deposit which is probably of the same age.

Ironstone and limestone were in earlier times dug out of the Wealden to supply the furnaces which then blazed all over this region (p. 118); and even now a brown iron ore, impure and sandy, but in some cases containing enough peroxide to yield 45 per cent. of metal, is mined at Seend near Devizes, and at Linslade in Buckinghamshire. The concretionary brown iron ore of Hanover also belongs to this Period. Chalk is applied to a variety of purposes, artistic and economic. Where found it is burnt to make lime for the use of the plasterer and farmer, and when "levigated" (that is, stirred up with water so as to allow the gritty and coarser particles to settle), constitutes "whiting."*

Flints (Fig. 136) were at one time chipped for the arrow-heads, spear-points, knives, and axes, of tribes unacquainted with the metals. At a later date they were employed for gun-flints and, in the days of tinder-boxes and similar means of obtaining a spark, had a certain commercial value. The latter use is nowadays almost obsolete, and though a great many bushels of gun-flints are still despatched to savage and semi-barbarous countries, the demand for them is yearly growing less and less, percussion caps and cartridges taking their place. Calcined and ground flints are, however, still employed for manufacturing fine porcelain and flint glass, and in the districts where they are common (as around London) form the universal road metal, the scrapings of such roads, owing to the silica of the mud, having a value as manure which is not possessed by those of either granite or trap. Sometimes they are employed for building purposes, and more frequently for facing or covering the outside of the walls, as so commonly seen in old houses and churches in Kent, and particularly in the ecclesiastical town of Canterbury.

Coal, we have seen (pp. 169, 172, 174, 175), is mined in Cretaceous deposits all over the world. In some cases this coal is a poorish kind of lignite, as in the Laramie Beds and Canadian North-West Territories; in other cases it is a fair bituminous coal, as in Vancouver Island; while in the Queen Charlotte Islands there are seams which the most experienced of American miners do not hesitate to compare with the best of Pennsylvanian anthracites. In the Wealden of North-Western Germany there are coal-seams thick enough to be mined, and in the Cenomanian of Saxony and the Senonian of Magdeburg there are beds of even greater importance, albeit only lignites. Lignite is also found near Rochelle, in the Lower portion of the System. In New Zealand the Upper Cretaceous contains only brown coals, though on the west coast seams of fair bituminous coal are associated with sandstones and conglomerates, which Sir James Hector is inclined to regard as the equivalents—in time, at least—of the Lower Greensand. To this period also the same coal-bearing group of Queensland, with Ammonites, Belemnites, and the remains of Ichthyosauri, may perhaps be referred.

The Cretaceous System is not notable for any very valuable building stones; still what are to be had are locally applied to a variety of purposes. Even chalk, though usually too friable and too easily acted on by the weather, is used as a bottom for roads cut through the

* "French chalk" is not chalk at all, but a fine variety of steatite or soapstone; "black chalk" is a soft variety of drawing-slate; and "brown chalk" is really umber.

Cretaceous and Eocene clays of the neighbourhood. The Faxoe limestones are sometimes used, not only for building purposes, but as flags for footpaths—a fact which the obser-

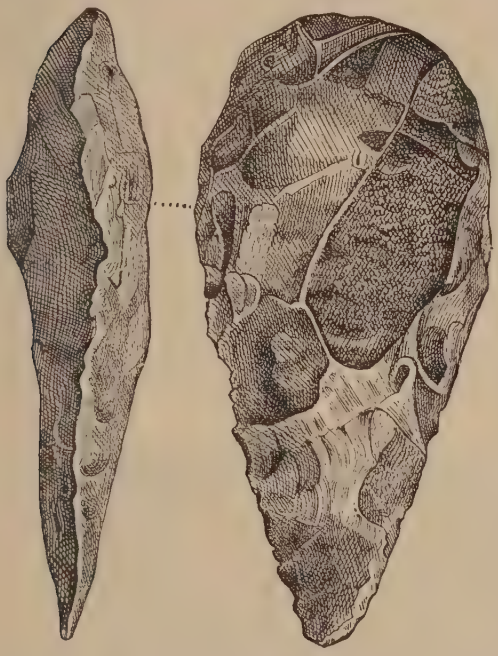


Fig. 136.—"PALÆOLITHIC" FLINT IMPLEMENT, FROM SAINT ACHEUL, NEAR AMIENS.

(Eleven inches long, by five wide).

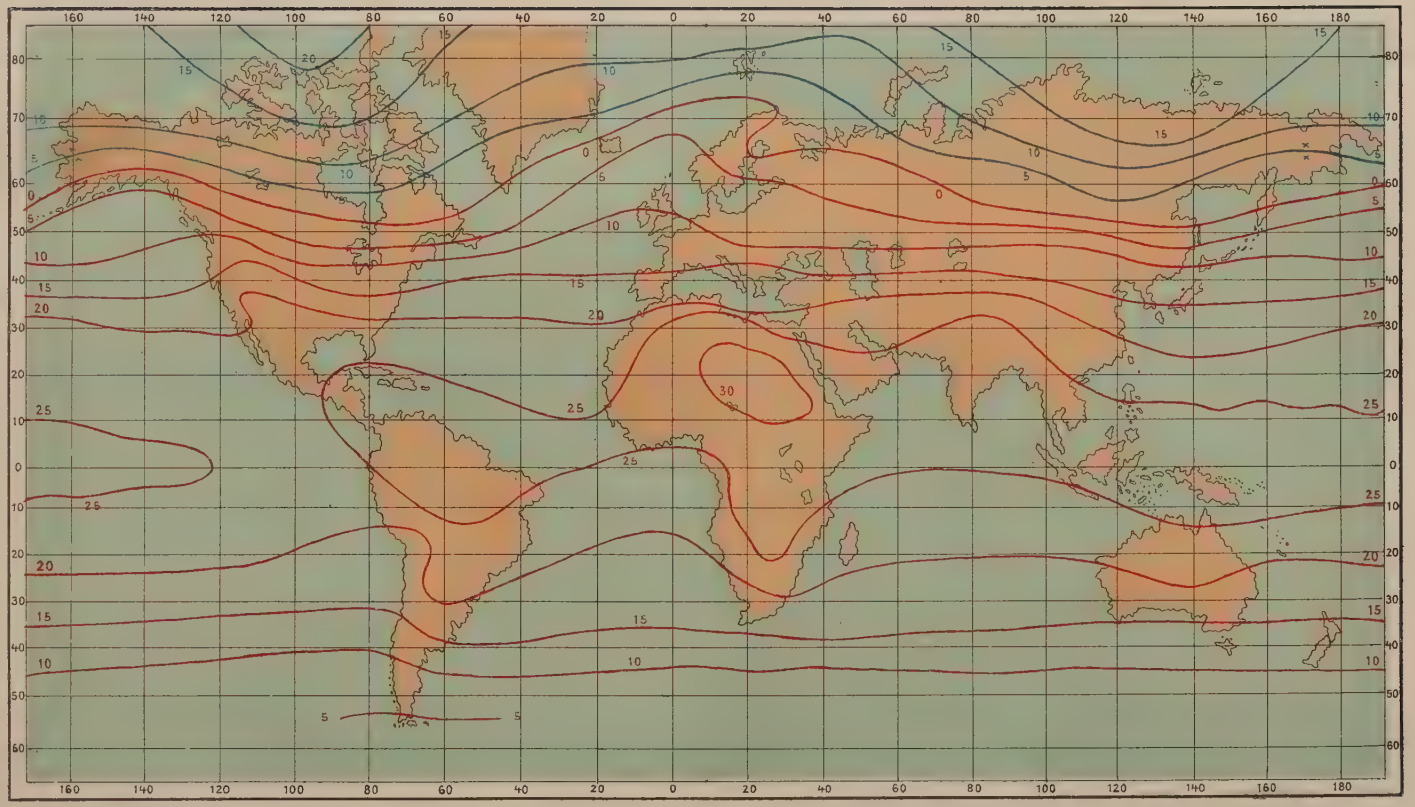
vant visitor to Copenhagen must have noticed, the wearing of many feet having made those in the Norgesgade, for example, so smooth that the Baculites, Belemnitellæ, and other characteristic fossils, can be easily recognised on the surface. The Bethersden or Paludinal marble (p. 166), which in quality is not unlike the Purbeck marble, is held in some esteem. The Kentish Rag and Chalk Marl are used in Cambridgeshire and Kent as building stones and for road metal. The Romans used it for their London wall. This "rag"—which is so very fossiliferous that it is often an impure limestone, close in texture, with grains of quartz—belongs to the Lower Greensand, which also is the Age of the coarse sandstones out of which so many of the Lincolnshire churches are built, though, owing to its want of durability, these buildings have generally an appearance of being sadly in want of the "restoration" not justified by their moderate antiquity. The "Carstone" of Norfolk—a yellow and brown sandstone containing black shining pebbles of quartz, chalcedony, flint, and slate—is also employed as a building stone. Finally, the septariæ of the "cement bed" of the Speeton Clay are mined to a large extent for the manufacture of Roman cement, the argillaceous limestone of these concretions being valuable on account of the rapid manner in which it sets and does not crack in drying, while the tenacious clay in which they are embedded is turned into the best quality of Portland cement. In the Lower Neocomian (or Valengian) of the Jura there are workable beds of the iron ore known as Limonite (Vol. I., p. 67), and, though there are limestones near Val-de-Travers most probably of Tertiary age, the chief deposit of the well-known asphalt (Vol. I., p. 64) is confined to a special zone in the Urgonian stage of the Albian or Gault. Its origin seems to be in the decomposition of the animal remains with which the white and grey limestones are so thickly studded. The old Lake Dwellers were well acquainted with this asphalt, for they used it to fix their arrow-heads to the wooden shafts.

From a sanitary point of view the Chalk is very important; for, owing to the rain being absorbed by it as fast as it falls, the soil is always dry, even the valleys being often without any streams flowing through them, though they bear the impress of having been hollowed out by running water. Many people feel a distinct exhilaration of spirits on reaching the dry air of the chalk country, and a corresponding depression when they descend again into the clay-covered valley of the Thames. Yet, though the Chalk absorbs the water, instead of, as is the case in clay-covered tracts, permitting it to lie on the surface, rain must necessarily percolate slowly through its not very permeable mass, unless where cracks and other fissures permit of its passage.

Owing to this aptitude for imbibing in the rainfall, the Chalk forms a great reservoir for water, held from sinking out of reach by the firm beds below. Water we know (Vol. I., p. 111) is contained in all rocks, their power of absorbing moisture being, as a rule, in a direct ratio to their porosity. But the quantity which a bed can hold when fully saturated is distinct from that which passes freely through it. Thus, as Prestwich has shown, both clay and chalk can absorb a great amount of water; but the one does not transmit any, while the other does steadily, though in a niggard manner. Sand in East Hertfordshire has the capacity of percolating through it 21·4 inches of the mean annual 25·8 inches of rainfall in that district, while chalk does not dispose of more than 9·5 inches out of an annual 26·4 inches. Hence the number of artesian and other wells which the Chalk supports, and the constant springs which flow from it to lower levels. On the other hand, owing to the capacity of rain charged with carbonic acid for dissolving out the lime found in all Cretaceous beds (Vol. I., p. 275), and especially in chalk which is almost entirely composed of it, the water passing through the system is more or less hard.*

* In addition to the literature of the Cretaceous System already quoted, the following papers and separate works may be usefully studied :—Price : "The Gault" (1879); Topley, *Quarterly Journal of the Geological Society*, Vol. XXIV., p. 472 (the Lower Cretaceous Beds of the Bas Boulonnais); Gosselet : "Esquisse Géologique du Nord de la France" (1881); Judd, *Quarterly Journal of the Geological Society*, Vol. XXXIV., p. 228 (Scottish Cretaceous Beds); Hinde : "Fossil Sponges in the British Museum" (1883), and "Fossil Sponge Spicules" (1880); Jukes-Browne: "Geology of Cambridge" (*Memoirs of the Geological Survey*, 1881); etc., etc.

Fig. 137.—KING AND QUEEN ROCKS, FLAMBOROUGH.



ANNUAL-ISOTHERMS

(IN DEGREES OF CELSIUS).

Fig. 138.—IDEAL LANDSCAPE OF THE EOCENE PERIOD.

CHAPTER XI.

The Cainozoic Rocks: The Eocene System.

No True Break between the Mesozoic and Cainozoic Epochs—Characteristics of the Former compared with the Latter—Classification of the Tertiaries—The Eocene and Oligocene System—Subdivisions—Principal Features and Fossils of these—Lower Eocene—Thanet Beds—Woolwich and Reading Series—The London Clay—Its Tropical and Semi-Tropical Plants and Animals—Middle Eocene—Bracklesham Beds—The Nummulitic Limestone—Tripoli and Infusorial Earths—Upper Eocene—Barton Clay and Upper Bagshot Sands—The Greenland Plant Beds—The Bovey Tracey Beds and the Leaf Beds of Antrim, Mull, and Skye—Lower Oligocene—Brockenhurst Beds—Foreign Equivalents—Amber Beds of North Germany—Middle Oligocene—Bembridge and Osborne Beds—Upper Oligocene—Hempstead Beds—Eocenes of India, New Zealand, Australia, and America—Extraordinary Fossil Finds in the Latter—Life of the Eocene Period—Physical Geography of the Period—Scenic and Economic Features—Agricultural Aspects of the System—etc.

Lying immediately above the Chalk is a series of formations which, following the customary nomenclature, are described as Tertiary, or, more generally, as *Cainozoic*, or "Recent Life," strata.* This classification, like all arrangements of the kind, is more or less artificial; for, though in England there is a distinct break between the lowest of the Cainozoic beds and the uppermost of the Mesozoic ones, this gap, indicative as it was at one time thought of a great interval of time having elapsed between the close of the one Period and the beginning of its successor, is now well known not to be of universal occurrence. The Thanet beds, so called from their forming the base of the London Basin in the district of Kent known by that name, lie

* Greek, *kainos*, recent; and *zoe*, life.

directly on the Chalk without any visible unconformability.* At the bottom of these Thanet beds there is a layer of green-coated flints, while the Chalk bears the marks of having suffered great erosion before the Eocene was deposited on this worn surface. The Chalk is often perforated by holes, which may have been those of boring marine animals, or the places in which sea-weeds were rooted. It is, therefore, more than probable that the passage beds which led from the one Period to the other were, in England, worn away by the sea, or other eroding agency, before the Eocene strata were deposited. The progress of geological science has shown that transition beds of this sort are of almost universal occurrence. There are in brief no sudden breaks in the geological record, the apparent gaps being due to these links having still to be discovered, or, as in the present instance, having been destroyed with their animal and vegetable remains. This conclusion is fortified by the rapidity with which the doctrine (at one time universally held) regarding the gap between the Upper Cretaceous and the Lower Eocene has been shaken. In Denmark the Faxoe Beds, in Holland the Maestricht Beds, and in France the Pisolite Limestone (pp. 172–174), have been shown to be strata with an admixture of Secondary and Tertiary fossils. Similar passage beds are found in Western America, in New Zealand (p. 174), Egypt, and Syria; and from the doubtful determination of the age of some of the plant-bearing rocks in Greenland, in Grinnell Land, the Mackenzie River district, and other parts of the Arctic Regions, it is far from improbable that in time similar links between the Secondary and Tertiary Epochs will be discovered in that area of the world. They should also be looked for in Algeria, Morocco, and other sections of unexplored North Africa. Finally, some of the Alpine shales, limestones and sandstones, locally known as "Flysch," may be regarded as partaking to a large extent of the same character. Even in England, the break between the life of the two Periods is not quite unbridgeable. The London Clay, for example, contains several genera—but not species—of sea-urchins which are characteristic of the Cretaceous Period, and we are reminded by Mr. Jukes-Browne that, wide though the difference between the fauna of the Eocene and of the Chalk undoubtedly is, the difference is not greater than that between the fauna of the latter and of the Chalk Marl immediately below it, the reason being that the Chalk Marl was deposited in comparatively shallow water, while the Chalk is, recent theories notwithstanding (p. 185), most likely a formation laid down in seas of considerable depth.

General Characteristics of the Tertiaries.—It is, therefore, not to be wondered at that the life of the Epoch we have left behind and that which we are now considering should be so far apart, for all of the Tertiary Formations bear to a large extent the impress of being those of shallow seas, estuaries, or lakes. In Great Britain one brachiopod—a *Terebratula*—seems, with the exception of a few lowly foraminifera, to be the sole survivor of the Cretaceous Epoch, while the general aspect of the Eocene animals, and to a less extent of the plants, is strangely different from that of the Period which it succeeded in chronological order. All of the great land and sea reptiles, all of the cuttle-fishes living in chambered shells—the Ammonites, Baculites, Scaphites, Hamites, Belemnites, etc., with the exception of the Nautilus, which still survives in the form of one species (*Nautilus pompilius*)—are inhabitants of Southern seas. The Inocerami and the Hippurites—so characteristic of the Chalk that the age of a piece of rock can be determined if one of them is present in it—are no longer to be seen, while some genera of univalve shells and some bivalves, with a host of the sea-urchin and star-fish family, corals, and deep-sea sponges, like Ventriculites, have shared their fate.

It is the same with larger forms of life. Mammals, which in Mesozoic times were comparatively few and small, are now numerous and of a vast variety of species, the marsupials, to which most of the earlier ones

* Whitaker, *Memoirs of the Geological Survey*, Vol. IV., p. 57.

belonged, having dwindled away to proportions something like what they occupy to the higher division of placental species at the present day. Elephants, for example, were numerous; so were Cetaceans (whales) and Sirenians (sea-cows), while in some formations seals of a variety of species are—like the two Orders mentioned—found for the first time in the history of Creation. The toothed birds, so characteristic of Mesozoic times, survive through the Early Eocene, one (p. 202) being found in the London Clay. But their day is over, and the numerous species with which we shall in future come into contact, are either great wingless forms, or types closely akin to those living in the countries out of the soil of which their progenitors are digged. The great reptiles of former Ages no longer swarm on either sea or land. The Ichthyosauri and the Plesiosauri have gone with the flying lizards and the long-legged Dinosaurs. The crocodiles, the turtles, and tortoises have survived up to our day, though it is unnecessary to add, in species different from those of the early Tertiary Ages. But neither they nor the other reptiles which took the place of their Mesozoic contemporaries are so numerous in the Eocene as they were in the Formations preceding it. True serpents, however, now for the first time make their entrance into a world which they do not adorn (p. 201), while the batrachian division of the Amphibia* also arrive about the same period. Ganoid fishes are few, while Teleostean, or bony-skeletoned species, get constantly more and more numerous.

Plants are also plentiful, and of types so high that while angiosperms† were wanting in Great Britain during Jurassic and Cretaceous times, they are now so numerous that over 200 species have been described from England alone, though on the Continent they were present at an earlier date. Cycads of the prevailing forms have "died out"—using a familiar expression to which the biologist has begun to object. Or they survive in some more tropical regions than those which their predecessors frequented, the migration of species seen in Cretaceous times having been impelled by the gradually increasing cold which befel the northern regions, at that time enjoying, as far north as Greenland and Spitzbergen, a climate equal to that under which the same kind of plants, exhumed from the rocks of those countries, flourish in California. During Tertiary times the flora began to more and more approximate to that now existing, though plants like palms are often found in combination with others of more temperate types like oaks, walnuts, figs, laurels, and firs, just as they are at present in Northern Africa and on the shores of the Mediterranean, which bask under a sun about as warm as that of the earlier Tertiary ages of Northern Europe and America. But the most remarkable of all the fossils of which we gain an inkling in the Tertiary beds are the remains of Man himself. As we shall see, his bones and his implements do not appear beyond the power of dispute until the dawn of what has on that account been termed the Quaternary or Anthropozoic Epoch (Fig. 139). Yet, though even the most enthusiastic advocates of the immense antiquity of the human race have scarcely ventured to seek for its ancestry in Eocene strata, there have been attempts to do so in Miocene beds, while it may be taken as proved that he was hunting the prehistoric beasts which roamed over Northern Europe before the appearance of the Glacial or Pleistocene Period.

In Tertiary times also the range of species which had been gradually getting more and more circumscribed, approached, before it closed, in many respects to that of their relatives at the present day. For example, Tertiary mammals which are dug

* The terms Amphibia and Batrachia are often used synonymously. Of late years, however, they have been begun to be applied in a more restricted sense. By some zoologists, accordingly, the Urodela are the tailed amphibians—the newts, sirens, salamanders, axolotls, etc.—while the Batrachia proper, or Anoura, are the frogs and toads.

† Angiosperms are plants which—like most of our modern types—have their seeds encased in seed-vessels, while conifers and cycads from lacking this characteristic are termed Gymnosperms or naked-seeded forms.

out of the earth of the South American Pampas, though not the same species as those now characteristic of those regions of the New World, are—like them—sloths, armadilloes, alpacas, and ant-eaters, in most cases of a more gigantic growth. In like manner the Australia of the same epoch was—as the Australia of our time is—inhabited by marsupials, mammals of the opossum and kangaroo Order, while New Zealand, then as now, was the home of wingless birds, like the apteryx and the moa, which there is every reason to believe was living in the antipodean islands when the Maori race first landed on them—an event of which traditional records have been preserved. This rule, however, only holds good in certain localities, for though in the Western American Tertiaries hosts of little horses and animals closely approaching them are found, the genus *Equus* is not nowadays represented by any native species which might be descended from those primitive Equidæ, the horse and the donkey having, of course, been introduced from Europe. Again, though elephants of various extinct species were during Tertiary times abundant in both Europe and America there are none living there in this Age of the Earth. Numerous similar examples might be cited of early Tertiary mammals which died without leaving any descendants in their old area. Indeed, the range of species seems to get more and more circumscribed the closer we approach our own period, many Palæozoic and Mesozoic species having had an almost world-wide distribution, while in Pliocene times most of the animals kept to the same great provinces which are characterised by their nearest allies in our times. It is clear, however, though the physical break between the Secondary and Tertiary epochs is not quite so pronounced as was at one time thought, that the palæontological gulf separating these two great stages in the earth's story is sufficiently broad. This is shown by the fact that though many Mesozoic genera survive, only one highly organised species — *Terebratula striata* (p. 194)—can be affirmed to have outlived the great changes which supervened on the close of the Mesozoic epoch. A general upheaval of the surface hitherto under water seems to have been the most salient geographical feature which marked the advent of Cainozoic times, and with this revolution in the relations of land and water—effected slowly, we may be sure, and in the course of a vast lapse of time, we are confident—an equally notable alteration in the inhabitants of the new lands and seas came about. The most notable aspect of this life was its more modern appearance: in brief, it was, as the name of the epoch signifies, "recent life," which before the close of the epoch became identical with that now inhabiting the earth. Shallow seas and estuaries were the prevailing features of this newer world. Much dry land existed, and the spots in which the deposits which now come to be described were laid down, appear to have been more or less isolated basins, each having beds more or less peculiar to itself. Hence, the frequent references which we must make to the London Basin, the Paris Basin, the Hampshire Basin, the Vienna Basin, (Fig. 149), and other Tertiary areas in Europe and elsewhere.

What brought about this extensive continental transformation is a question which it would be vain to try and answer. We have learned that there is not a movement in the earth's crust in ancient times which could not be duplicated in modern times. The earlier ones may have been—and in many cases were—more violent, but even the oscillations of the earth of which we know something are quite capable, if continued long enough, of causing changes not less remarkable than those which we are now called upon to study (Vol. I., pp. 167–177). These changes of level would necessarily be accompanied by alterations in the line of drainage, so that new rivers, lakes, and inland seas would be formed. These, in their turn, would effect striking changes in the climate, while the course of the marine currents would necessarily be deflected, and, consequently, the temperature of the seas influenced by

Fig. 139.—VIEW OF A PREHISTORIC GRAVEYARD OF THE LATE QUATERNARY PERIOD, NEAR KLENIK, NOT FAR FROM LITTAI IN CARNIOLA, AUSTRIA. (*After a Sketch by Von Benesch, in September*, 1878.)

them altered. The result of this revolution in the orography and climate of the world could not but have a corresponding reaction on its flora and fauna. Hence we find that, though here and there the old Mesozoic forms lingered on, having migrated to regions where the changes were less marked, the endless vicissitudes were too much for them, so that even in Australia and America the saurians and cephalopods of the preceding Epoch survived for a comparatively short time only. As Mr. Prestwich has put it, "adaptability and the faculty of migration having a limit, the old types became fewer with each succeeding change of condition, until they ultimately succumbed to the unceasing vicissitudes."

During the Tertiary epoch some of the most remarkable changes in the physical features of the globe took place. As the Nummulitic Limestone now reposes at the height of more than 16,000 feet above the sea in which it was laid down, the Alps and other ranges must have risen in this Era, while the ever-increasing cold of the Tertiary Ages culminated in a time when the Northern hemisphere was overwhelmed by glacier ice, after which a temperate climate once more obtained.

Beds laid down under the conditions described may naturally be expected to be of extremely varied consistency so far as clays, gravels, and sands can partake of distinctive characteristics. On the other hand, many of the Tertiary deposits, though they are evidently from the contained fossils of widely different ages, present throughout almost no change in mineral texture. Add to this the fact that, instead of the Tertiary strata stretching over great areas and attaining an immense thickness, they are very local and, as a rule, of comparatively small depth, and we may still further appreciate the broad differences between them and the Mesozoic rocks.

Classification. — These peculiarities, however, make their classification difficult. The leading divisions are not puzzling, but when we undertake to say whether one local bed is older or newer than another a few miles away, or even that it is its equivalent in time, fossil contents do not always afford that firm basis of comparison which they do in the study of the older strata. Still, mainly owing to their development in the vicinity of three great capitals, and the archæological interest attaching to the remains found in their upper layers, the Tertiaries have attracted more attention from geologists than almost any other strata, though the space which they fill in the chronicles of the Earth cannot be compared with that occupied in laying down either the Mesozoic or the Palæozoic Formations. Accordingly, we are able to arrange the leading members of the series with more accuracy than would have been possible had the rocks composing them been situated at a greater distance from the centres of scientific intelligence.

However, if sporadically distributed in moderately-sized patches, the Tertiary Systems have representatives in almost every part of the world, though the distribution of the beds indicating the particular ages—Eocene, Miocene, Pliocene, Pleistocene—is more restricted.

It has already been remarked that the most notable feature about the Cainozoic rocks is, that in all of them there is a certain percentage of species identical with those now living, and that these percentages increase from the lower to the higher beds, until, in the uppermost division of all, there is only a small minority of extinct forms. These facts have been taken as the basis for their classification, though it may be as well to observe that the exact ratio of dead to living forms is no longer very strictly observed by geologists in assigning a bed to a particular system. Thus a rock, which it is clear from the associated fossils is an Eocene or a Pliocene one, is placed in that system without taking into account the precise percentage of living shell-fish which it may contain, Lyell having founded his classification on a study of European strata alone. But the general facts still hold true, and the arrangement adopted is that universally observed, with minor modifications, by geologists all the world over. Thus the order of the Tertiaries is

(1) the *Eocene*,* which in Europe contains about 3½ per cent. of existing species; (2) the *Miocene*,† containing a greater number—namely 17 per cent.; (3) the *Pliocene*,‡ a still newer set of beds, in which the living species exceed one half of their entire contents, the percentage ranging from 30 per cent. in the lower beds to 95 in the upper ones; lastly (4) the *Pleistocene*§ system, comprising that series of deposits in which nearly all of the mollusca (and, for convenience' sake, shells being the best preserved forms have been taken as the basis of comparison) are of living species, though most of the mammals belong to extinct forms.

In addition to these divisions, geologists have of late years begun to adopt a proposal made long ago, to introduce between the Eocene and the Miocene an *Oligocene*‖ group, by uniting the upper portion of the one system with the lower portion of the other into a separate system. In a general sketch this excessive sub-division is, perhaps, unnecessary. Accordingly, we shall continue to look upon the Oligocene as a portion of the Eocene, preserving, however, the classification proposed by those who allot to it a higher position. In like manner, we shall continue to rank the Pleistocene, or Glacial Era, with the Tertiaries proper (p. 55), reserving the Quaternary, Anthropozoic, or Post-Tertiary, Epoch for what is sometimes called the Post-Glacial and recent Formations, in which nearly all of the animal and vegetable remains are identical with living species, and in which the remains of man repose in deposits formed under circumstances admitting of no dispute, owing to their origin being, geologically speaking, very modern. In this way, even at the cost of occasionally crossing the prevailing current of a rather shifting opinion, we can more intelligibly describe the leading facts with which the next four chapters are charged. All the classifications proposed for the Tertiaries are, however, more or less artificial, the division lines being by no means well marked, so that convenience more than anything else must be consulted in choosing among the proffered gifts of this description. It has, for instance, been suggested ¶ that the Eocene and Oligocene should be united into a system of the first order, under the name of *Hantonian*, from their typical development in Hants and the Isle of Wight; while the Miocene, Pliocene, and Pleistocene might be bracketed as *Icenian*, from the old British tribe of Iceni, who inhabited the eastern district, where the two latter groups are typically deposited in Great Britain. The Miocene has even been regarded as a transition group. Finally—though we do not exhaust the proposals—the Eocene and the Oligocene have been classified as Palæogene, or Older Tertiary, while the other members of this Epoch—the fossils of which are indicative of a cooler climate than those of the earlier rocks—are described as Neogene, or Younger Tertiary. All this is interesting and possibly useful, but by being less ambitious and more conservative, the reader may, perhaps, not lose a great deal.

* Greek, *eos*, dawn; *kainos*, recent.
† Greek, *meion*, less; *kainos*.
‡ Greek, *pleion*, more; *kainos*.
§ Greek, *pleistos*, most; *kainos*.
‖ Greek, *oligos*, few; *kainos*.

Eocene System.

This system lies at the base of the Cainozoic rocks. In England the chief Eocene areas are the London and Hampshire Basins, though not unlikely its range was at one time over the whole south-east of England, denudation having shaved it off all the higher grounds intervening between the coasts of Dorset and Suffolk. On the Continent of Europe Eocene beds are found in various Basins in Belgium, France, Spain, and Greece. They enter into the structure of various mountain ranges, such as the Carpathians, the Alps, and the Apennines, and stretch into Egypt, Asia Minor, Persia, and Northern India, and have been detected in Japan and China. In America, Eocene beds occur at various places around both the Atlantic and the Pacific shores, and some of the fresh-

¶ Jukes-Browne, *Geological Magazine*, Dec. 3, Vol. II., p. 293.

water deposits of the Rocky Mountain region, in which so extraordinary an assemblage of mammals, including those curious horse-like forms, has been found. The Upper Division, termed Oligocene, is in England confined to Hampshire, the Isle of Wight, and Devonshire, but where the beds in question lie over the Eocene, the passage between the two is perfectly conformable. In the Paris and Belgium Basins they also overlie the Eocene, but in Germany, owing to the latter being absent, they are the oldest of the Tertiaries. In Switzerland the lower portion of the conglomerates and sandstones known as the "Molasse" belongs to this division, while the Vienna Basin, Italy (Liguria), Alsace, various parts of South-West Germany, and the adjoining borders of Switzerland and France (the Bohnerz Formation of the Jura—the *Depôts sidérolithiques* of the French writers—an accumulation from mineral springs or possibly from mud volcanoes, containing the bones of mammals), and Auvergne (where there are fresh-water deposits with skeletons of birds, reptiles, and mammals), are among the other European Oligocene localities. In North America they occur in the "Vicksburg" Beds of Florida, which also stretch into Mississippi, Alabama, Louisiana, Georgia, and Texas, and are especially characterised by the presence of *Orbitoides mantelli*, a fossil which ranges over so wide a region that it is also found on the borders of Turkey and Persia.

Fig. 140.—EOCENE MAMMALS.

A, Palæotherium magnum; B, Anoplotherium commune; C, Xiphodon gracile.

Sub-divisions of the Eocene. — Beds so little continuous as the clays, sands, loams, and gravels of the Eocene and Oligocene are, like the other constituent members of the Tertiaries, by no means easy to classify, and still more difficult to correlate with any confidence. The following brief synopsis may, however, be accepted as representing the views generally held as to the succession of the Eocene and Oligocene beds, the series running from below upwards.

(1) *Lower Eocene.* — In England (*a*) the *Thanet Sands* — marine deposits of lightish-coloured or greenish sands about ninety feet thick—constitute the lowest member of the series. Above them are (*b*) the *Woolwich and Reading Series*—mottled clays, loams, gravels, and sands, with lignite, estuarine, or semi-marine deposits, with some land-plants, apparently washed into them by river-action; they are, however, very irregular, both in character and thickness. (*c*) The *Oldhaven beds* (so called from Oldhaven Gap, between Herne Bay and the Reculvers) also contain a few land-plants, though their fossils are chiefly marine, or, in some instances, estuarine. They are constituted * out of the upper pebbly beds, including the Sundridge ones and the "basement bed" of the London Clay, though this division is not universally recognised as distinct from ones above and below it. The uppermost division of the Lower Eocene is the well-known (*d*) *London Clay*—the dark brown or greyish clay with septarian nodules,†

* Whitaker, *Quart. Journ. of the Geological Society*, Vol. XXII., p. 412, and "Geology of the London Basin," p. 239.

† These are irregularly-shaped masses of clayey limestone with "septa" or divisions of calcspar or arragonite.

which, unfortunately, underlies so much of the site of London. It is, however, also seen in the Hampshire Basin (Bognor Beds), where, in addition to clays, it contains beds of clayey sandstone and conglomerate. Altogether the London Clay will, in places, attain a thickness of 500 feet, and, though it contains the remains of many terrestrial animals and plants (which indicate a tropical or sub-tropical climate), must be regarded as essentially a marine deposit. It is seen mainly in the valley of the Lower Thames, but it seems at one time to have extended considerably farther, deposits of it having been found as far as whose relatives nowadays do not affect our Northern seas. As Sir Richard Owen remarks,* there have been found in the London Clay of Kent and Essex remains of more species of turtles than are now known to exist in the whole modern world. Of this number (fifteen), one—the *Chelone gigas*—had a head 18 inches long by 14½ broad, while, in addition to two crocodiles near akin to that of the Ganges, the remains of a serpent (*Palæophis toliapicus*) 12 feet long have been disinterred from the soil on which stands the capital of the British Empire. As for the mammals, most of them are tapirs, a family

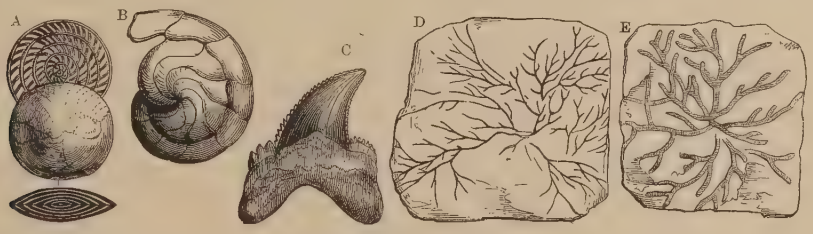


Fig. 141.—EOCENE FOSSILS.

A, Nummulites (transverse and vertical sections); B, Nautilus (Aturia) lingulatus; C, Carcharodon heterodon (a shark's tooth); D, Pseudofucoids (doubtful sea-weeds), Chrondrites intricatus; and E, Chrondrites targionii, from the "Flysch" Formation, now considered—like C. bollensis of the Lias, and C. ehingensis of the White Jura—to be worm tracks.

French Flanders and Belgium, at St. Marguerite near Dieppe, and, among other places, at the base of the Hill of Cassel, near Dunkirk. It shows that at the time it was laid down the valley of the Thames was occupied by an inlet of the sea, opening, most likely, if not to the Atlantic, into a Southern Mediterranean, and so broad that it extended in one direction to Herne Bay, and in another to Highgate Hill, the roadway over which the Highgate Arch is thrown having been cut through a deep accumulation of it containing many of the most familiar fossils of the Formation. In the "basement bed" small marsupials have been found, while, in addition to many other fishes, there occur sharks (including one probably 40 feet long), another species allied to the modern Barracadus (a voracious fish of tropical seas), a mackerel of a genus now inhabiting the tropical Atlantic and Indian Oceans, and several others now found mainly in South America, though some of those from the London Clay are thought to have affinities with the Malayan species (Figs. 138, 140). The plants are represented by a great many fruits and seeds, with occasional trunks and fragments of wood. The fruits, like most of the shells, are casts in iron pyrites, though wonderfully well preserved. Near Whitstable, the metropolis of the East Coast oyster-dredgers, the cones of a sequoia (*S. richardsoni*), a tree of which the only two living species are confined to California, have been disinterred, while the shore at Sheppey is strewn with the remains of the agaves, smilax, musa (banana), fan-palms, dwarf-palms, cabbage-palms, and one—very common—which is almost identical with the African oil-palm. Screw-pines (Pandanaceæ), the "fossil figs" of the uninstructed collectors, are so numerous that at

* "Palæontology," p. 281.

least five species have been detected, while, in addition to trees of a more temperate climate—oaks, walnuts, limes, chestnuts, etc. —we find great logs honeycombed by shipworms and boring annelids, just as floating timber is at this day.*

These and the other fossils which are found in the London Clay leave little doubt that this notable deposit was an accumulation of silt from a huge muddy river rolling seaward through a country with a climate like that of Southern Brazil, and which embedded in this delta, or in the sediment which during its floods it left on the banks, the animals which swam in its estuary or were washed into its current, and the fruits which dropped from the trees on the overhanging banks. In short, Kent, Surrey, Berkshire, Middlesex, and Hampshire, were in Lower Eocene times pestilential regions covered with a dense semi-tropical vegetation, through which crocodiles and serpents crawled, and great birds like the *Gastornis klasseni* of the Croydon beds stalked, while the web-footed *Odontopteryx toliapicus*—one of the last of the toothed birds—seems still to have lingered on in the lakes or bays of the Period, struggling in unequal strife with the crocodiles of the same localities. Finally, all around the shores and estuaries of this Eocene sea, turtles of many species crawled lazily, without any enemy to fear (Fig. 138).

In addition to the Continental equivalents of the Lower Eocene already mentioned (in Belgium and France—for they are entirely wanting in Germany, Switzerland, and Italy), beds containing very much the same fossils as the London Clay, and lignites with numerous plants, are found in North America at Clairborne in Alabama, though some of the beds there evidently belong to the Middle Eocene.

(2) *Middle Eocene.*—In England, this division is represented by (*e*) the *Bracklesham Beds* and Middle and Lower *Bagshot Sands* marine beds, mainly sands, clays, and gravels upwards of 700 feet in thickness, some fossiliferous, others singularly bare of the remains of organisms, while at Bournemouth and Alum Bay the Middle Eocene beds contain an abundant flora. On the European continent the Calcaire Grossier of the Paris Basin, and the Nummulitic beds of Reichenhall in Germany and the Nummulitic and Fucoidal beds of Northern Italy are the chief equivalents of the Middle Eocene. The Calcaire Grossier consists of various limestones, the lower beds of which are full of nummulites and oysters, while the middle bed (the Miliolite limestone) is composed mainly of foraminifera (Orbitolites and Triloculinæ). Of one univalve mollusc (*Cerithium*) fully 150 species occur, one of them (*C. giganteum*)—very characteristic of the deposit—being often a foot in length.† This limestone, in its higher part, supplies most of the excellent building stone of Paris, and has a classical place in the history of geology from the fact that in this formation were found the bones which enabled Cuvier to establish the existence of the *Palæotherium* and other Eocene pachyderms (Fig. 140, A).

The Nummulite limestones are not less notable. They derive their name from being almost composed of a large foraminifer (*Nummulites*), many species of which are known. In appearance they are not unlike a coin: hence their scientific name (Fig. 141, A).‡ They must have occurred in inconceivable numbers, since the limestone, of which they are almost the sole constituent, plays a much more conspicuous part than any other Tertiary rock in the solid framework of the earth's crust. It often attains a thickness of several thousand feet, and is found in the Alps, the Carpathians, and in Morocco and Algeria. The old pyramid builders knew it well, and

* Bowerbank: "History of the Fossil Fruits and Seeds of the London Clay" (1840); v. Ettinghausen, *Proceedings of the Royal Society*, Vol. XXIX., p. 288; v. Ettinghausen and Gardner's monographs on the "British Eocene Flora" (Palæontographical Society, 1879–1885); Boyd-Dawkins: "Early Man in Britain" (1880), pp. 13–123, in which will be found an excellent summary of the palæontology of the British Tertiaries, so far as the higher animals are concerned, etc.

† Deshayes ("Description des Coquilles Fossiles des Environs de Paris") describes over 400 species from the French deposits alone.

‡ Latin, *nummus*, money, a coin.

utilised it so extensively in the construction of their massive monuments, that Herodotus, seeing the loose nummulites above their base, suggested that these fossils were the remains of the lentils which the labourers had used as food. In Asia Minor this limestone again appears, and it can be traced across Persia, by way of Baghdad, to the mouth of the Indus. Cutch has it in quantities; and, according to Lyell, it enters into the mountain ranges which separate Sindh from Persia, and which form the passes leading to Cabul, and it has been followed as far as Eastern Bengal, and the frontiers of China, and even to the Philippine Islands, so that this remarkable Formation constitutes a rocky girdle round the earth.

Some of the "tripoli" or "infusorial" earths seem to date from this Age, though occasional deposits (p. 216) are to be assigned to a later period. The former substance, which in many parts of the world attains a considerable thickness, consists almost entirely of the flinty cases of diatoms. The latter, found, among other places, in Barbadoes, is for the most part made up of the delicate shells of Polycystinæ—lowly protozoons, mere specks of jelly surrounded by a shell, which do not exceed a grain of sand in size when they are not altogether microscopic. Some of the Alpine beds which go by the general name of "Flysch"* and "Vienna Sandstone" (Fig. 149) may also be referred to this Period, though they seldom contain any fossils except fucoid or seaweed-like plants. These do not afford any very sure guide to their classification, and, of late, Nathorst has maintained that the so-called "fucoids" of the Flysch, and probably of the Monte Bolca beds near Verona in Northern Italy (which contain nummulites in addition), are simply the tracks of worms (Fig. 141).

(3) *Upper Eocene.*—The chief English representatives of this section are (*f*) the *Barton Clay and Upper Bagshot Sands*, the first consisting for the most part of clay and sand confined to the Hampshire Basin, and swarming with marine fossils, while the second consist of yellowish and white sands and clays. The Barton Clays are well exhibited in the High Cliff near Barton, Hordwell, and at Alum Bay in the Isle of Wight; while the Upper Bagshot Sands, which are usually claimed to be of the same Age, derive their name from a well-known locality within the London Basin.

Many of the Eocene beds are full of plants. For instance—not to speak of the London clay, with its wealth of tropical and semi-tropical fruits—the "Bracklesham Sands" at Bournemouth contain, in a very fine sandy clay, many species preserved in an admirable condition. Instead of the numerous palms which are characteristic of the Wareham Beds, ferns of tropical and sub-tropical types predominate, many of them showing a striking relationship to those of America, Eastern Asia, and Java, while two only are of European types. One, *Chrysodium*, is apparently identical with *C. aureum* of Bermuda, while an *Osmunda* or "Royal fern" is not to be distinguished from *O. javanica*, a living species of the Eastern hemisphere. In Greenland an even more remarkable series of plant beds is found in the same area where the Cretaceous ones are situated. Those of Ounartok, at one time set down like the rest of them as Miocene, are now thought to be Eocene, belonging to this division, if not to a still more recent group. On the shores of Disco Island, so far as yet investigated (though denudation has long ago effaced most of them), they consist of sandstones containing two species of *Magnolia*, two planes, a *Viburnum* (*V. marginatum*), identical with a species found in the Laramie Beds, an oak, a vine, a walnut, and one of the many sequoias characteristic of Tertiary times.

At Atanikerdluk, on the Noursoak shore of the Waigat Strait, more than 180 species of plants have been found, including many forms common to the Laramie Beds, the Mackenzie River banks, and other localities in North-West Canada and the Western United States. This also seems to be an

* These "Flysch" beds have given rise to a voluminous literature, in which various positions are assigned to them in the Lower Tertiaries.

Eocene or an Oligocene Formation.* During the entire period occupied by the deposition of these far northern Cretaceous and Tertiary beds, the climate of Greenland seems to have been temperate, though the upper ones begin to show that the atmosphere had commenced to grow colder from the time when the plants already described (p. 176) flourished, a deterioration which went on until the Polar Basin sank to its present frigid character, while more Southern regions, which in early Tertiary days were tropical, became temperate, then Arctic, and finally what they now are.

These Greenland Eocenes are intercalated between sheets of basalt, and intersected by great dykes of the same material which stand out boldly in a wall-shaped form, owing to the softer beds—including those of coal, associated with them—having crumbled into dust under the Arctic atmosphere. Beds under somewhat similar conditions are found at Antrim in Ireland, and at Mull and Skye in the Hebrides. In the former locality about thirty species of plants have been found, and from the latter about a third as many have been described, comprising the usual sequoias, a *Viburnum*, etc., some of which are identical with species found in the Arctic Regions and in Western America.

Fig. 142.—BRANCH OF EUCALYPTUS (RESTORED.)

Again, at Bovey Tracey—a valley on the eastern slope of Dartmoor in Devonshire—a small deposit of almost pure kaolin and grits, derived from the decomposing granite of the neighbourhood, contains a flora consisting of some forty-nine species of plants—vine, fig, oak, laurel, cinnamon, *Gardenia*, *Nymphæa* (water lily), *Eucalyptus* (Fig. 142), etc., including several of the Southern order Proteaceæ, and a peculiar sequoia (*S. couttsiæ*) the cones and twigs of which form, with a fern, peaty masses of beds of lignite.† At one

* Gardner, *Palæontographical Society's* "Monographs," 1879–84; and Steenstrup, Heer, and Johnstrup, for the latest views, in "Meddelelser om Grönland," Hefte V. (1883), pp. 43, 79, 215, 217.

† Pengelly and Heer, "The Lignites of Bovey Tracey" (*Philosophical Transactions*, 1862); Gardner, *Palæontographical Society's* "Monographs," 1879, 1884, etc.

time all of these plant beds were considered to be Miocene; at a later date they were removed into the Oligocene division, but the probability is that they are Eocene, and may be placed in about the middle of the series.

(4) *Lower Oligocene.*—To this section the (*g*) *Headon and Brockenhurst Beds* (clays, marls, limestone, and sands) are assigned. They are very variable in character, and range from fresh-water and brackish beds at their base, through marine and estuarine ones in the middle, to fresh-water ones on the top. They belong, like the rest of the British Oligocene, to what are known as the "fluvio-marine series," which are well displayed in the cliffs from Alum Bay to Sconce Point in the Isle of Wight, at the other end of the island at Whitecliff Bay and Bembridge, and on the Hampshire coast from Barton near Christchurch, to Milford near Lymington. Their French equivalents are the Calcaire of Brie and the gypsum-bearing marls of Montmartre, while the beds which can be most certainly assigned as of the same age in Germany are the Lignites and Amber Beds of the north, while in Belgium the sands of Neerrepen, Grimmertingen, and Tongres, are regarded as their equivalents.

The Montmartre Beds are well known from having been so largely quarried for the sake of their masses of gypsum used in manufacturing plaster of Paris, and the marls which furnished the materials out of which Cuvier may be considered to have laid the foundation of palæontological science.* The Calcaire of Brie is a travertine containing large concretionary blocks of silex, while the "Meulières de Montmorency" at the top of the series are, with their associated sandstones, largely worked in the neighbourhood of La Ferté-sous-Jouarre for millstones and basement-walls. The German Oligocene contains thick beds of lignite, some of the yellowish varieties of which are fusible like wax, and used in the manufacture of paraffin. The amber lumps of Samland, on the shores of the Baltic, are dug out of a layer of greenish sand just below the level of the sea, which is overlaid by sixty or seventy feet of green sands, with trunks of *Taxites*, *Taxodium*, cinnamon, and other sub-tropical plants. The amber itself is the resin of *Pinus succinifer*

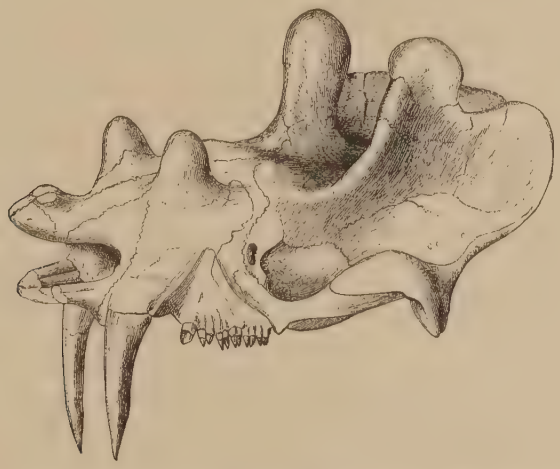


Fig. 143.—SKULL OF DINOCERAS MIRABILE (MARSH), FROM THE MIDDLE EOCENE OF WYOMING NORTH AMERICA.

* "Ossements Fossiles" (1824)—a work which may be compared with Linnæus's "Systema Naturæ" and Darwin's "Origin of Species," so far as its influence on the progress and tendency of biology was concerned.

and other species, the character of which is readily detected by the leaves, seeds, and cones perfectly preserved in the transparent pieces of the amber, along with the insects which crawled on their bark (Figs. 22, 23). Notwithstanding the fact that these beds have been worked for many centuries, they still yield largely, their precious contents being obtained either by digging, or by the action of the sea in washing the resin out of the earth. Specimens, indeed, may be found on the shore of the Sound as far west as Seeland, and as far south as the Zuyder Zee. It is even found in Spain, Italy, and Sicily—though these Southern deposits are not coterminous with the Northern one.

(5) *Middle Oligocene.*—In England these are represented by the (*h*) *Bembridge and Osborne Beds* of the Isle of Wight. In France their equivalents are the Phosphorites of Quercy, the Sands of Étampes and Fontainebleau. In Germany they claim kindred with the Clays of Stettin and Weinheim and the Clays and Sands of Egeln and Magdeburg, while in Switzerland the Glarus Slates seem to be their nearest relatives.

(6) *Upper Oligocene.*—This section, which in Belgium is represented by the Clays of Boom and the Sands of Klein-Spauwen, in France by the Marls of La Limagne and the Calcaire of Beauce, in Germany by the Sands of Cassel and the Marls and Lignites of Osnabrück, and in Switzerland by the Red Molasse, and the "Nagelfluh" of the Righi (a red conglomerate the pebbles of which are derived from the Vosges and the Black Forest), is not fully developed in England. The (*i*) *Hempstead Beds*—fresh-water marls and clays, capped by clays of marine origin—seem, however, assignable to this division. The deposit (well exposed in a cliff near Hempstead Farm, two miles east of Yarmouth in the Isle of Wight) is a very small one, containing numerous shells, imperfect leaf-impressions, seeds, etc., including (Fig. 152) a fan-palm (*Sabal major*) and a *Nelumbium*.

These collations of the English and Continental Oligocene may be regarded as a statement of the views most generally entertained. But when we try to bring the Eocene and Oligocene beds out of Europe into line with the better known ones described, we find ourselves much farther afield. It is, therefore, not worth endeavouring in this outline to assign to their due place the older Tertiaries of Sindh, the Punjab, Assam, Burmah, Cutch, and the West Coast of India; the less marked ones of Australia, or the passage beds (p. 174) of New Zealand, some of which contain gold drift, though it is probable that they range from the lowest to the highest member of the Epoch. In North America we have seen that there are representatives of many of the Tertiary systems; the Alabama group being probably the equivalent of the European Oligocene, though in the Wyoming Basin there are beds containing fossils allied to the European *Lophiodon* and *Palæotherium*. These beds have yielded to the investigations of Marsh, Leidy, Cope, and others, a most amazing collection of animals, monkeys (*Notharctus*), marsupials, allies of the horse, and, above all, the horned pachyderms (Dinocerata), which include several genera as large as an elephant, with two or more pairs of horns, and powerful canine tusks (Fig. 143). This group, which has left no descendants, was remarkable for the extreme smallness of their brains. Still more recently, in the Puerco beds of New Mexico, which seem to occupy the debatable ground between the Upper Cretaceous and the Lower Eocene, an enormous find of vertebrate animals has been made. From these strata Cope has described 106 species—12 reptiles, 1 bird, and 93 mammals. Besides a snapping tortoise (*Chelydra crassa*), the reptiles present little that is noteworthy, except that three of the aquatic saurians of the genus *Champsosaurus* have their nearest relations in the Laramie Period. The mammalia are, however, very interesting; with the exception of "four possible lemurs," they all belong to extinct families and sub-orders. Eleven belong to the same order as the Australian duck-bill, forty-nine are flesh eaters, and twenty-six are of hoofed types. "All the forms," Professor Cope adds, "show themselves to be the ancestors of the

later and modern mammals, by the indubitable character of their structure."*

Life of the Period.—This has already been indicated in the course of the preceding pages as consisting of nearly every animal and vegetable group, though, throughout the Eocene and Oligocene Ages, the species speak most decidedly of a warm, or even a tropical, climate.

The Nummulites are one of the few families which have no modern representatives, but many of the shells, if not identical with living species, have allies near akin in Southern seas, none of them being of an utterly bizarre character. The vertebrate animals were equally of familiar types—crocodiles, tortoises, and sea-serpents—while the birds, with the exception of the toothed *Odontopteryx* (p. 202), were of modern affinities. The mammals, if we leave out of account the extraordinary finds in Western America, were not comparable with those of succeeding Ages. They were in many cases pachyderms — the tapir-like *Palæotherium* (Fig. 140, A), the *Anoplotherium* (Fig. 140, B), a kind of transition between swine and ruminants; and *Xiphodon* (Fig. 140, C), another animal of the same family, the ex-

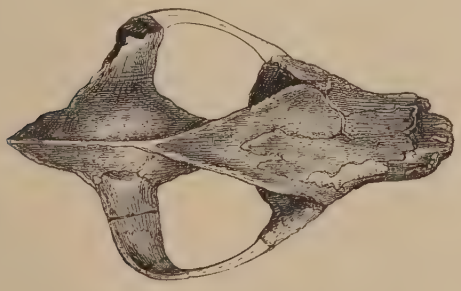


Fig. 144.—SKULL OF ARCTOCYON. (*After Gaudry.*)

tinct Anoplotheridæ; besides *Arctocyon* (Fig. 144), with the brain of an opossum and the teeth of a bear; *Palæonictis*, which had affinities with the "Tasmanian devil," or Dasyurus; and in the Upper Eocene *Anchitherium*, akin at once to the Palæotherium and the modern horse. It had three hoofs, or rather one hoof divided into three, and is believed to be one of the ancestors of the genus *Equus*. From the American Eocene are also obtained the four-hoofed and five-hoofed *Eohippus*, another link in the genealogy of the horse, besides the Dinocerata already described. In addition to these mammals there were wolverines, foxes—or fox-like animals—wolves—or wolf-like animals—though all possessing marsupial taints, besides hedgehogs, squirrels, and bats, mingled with the bones of pelicans, quails, the ibis, the flamingo, and the African hornbill.† It may be added that out of the Swiss Eocene has been disinterred the bones of the first known monkey, the lemuroid *Cænopithecus*, while the Wyoming beds contain the remains of several species of the same humble type of the quadrumana.

Physical Geography of the Period.—Though the Eocene beds of America occupy a very large area, it is probable that they—like those of Europe—were deposited in one of the inland seas, lakes, or basins, formed by the rise of the sea-bottom soon after the close of the Cretaceous Period. In the area occupied by the Eocene of France, Belgium, and Britain, there are signs of the agent occupied in laying down the deposits described having been a river or rivers draining a wide region, probably extending as far as Norway (then united with Britain), the banks of which were lined with tropical vegetation and haunted by tropical animals, while on the sandy "bars" of the main current and its tributaries great crocodiles basked, and in the lower reaches of the stream, where it reached an estuary, numbers of turtles lay, just as they lie at the present time on the sandy beaches of the sun lands. At that period it is in accordance with facts to infer that the sea in which the Upper Eocene and Oligocene rocks of the Isle of Wight were deposited, was shut off from the Atlantic by a barrier of land running due south from Dorset, Devon, and Cornwall towards Normandy and Brittany, the main body of the ocean being

* *Science*, Vol. XI., No. 273 (1888), p. 198.

† Boyd Dawkins: "Early Man in Britain," Chapter II.; Milne-Edwards: "Oiseaux fossiles," Vol. II., etc.

to the east or south-east, and extending at least as far to the north as Denmark.* At that period the Mediterranean stretched in a series of more or less continuous inland seas as far as the Indian Ocean, the mountains which are now the Himalayas being at that time little more than low hills bordering its shore, or islands rising out of the Eocene sea which laved them, while in Europe the Alps, the Carpathians, and the Pyrenees, have all been elevated since the close of the Period in question, as is evident from the nummulitic

The climate of the Northern Hemisphere—and, so far as we are able to judge from the fossils of the New Zealand beds, that of the Southern Hemisphere also—was during the entire Eocene and Oligocene Age of a tropical or semi-tropical character, though the shifting conditions exhibited in the Oligocene of Switzerland, Germany, and Southern Europe, during the period just before the advent of Miocene times, render it not improbable that there were many variations of temperature, the records of which have been imperfectly

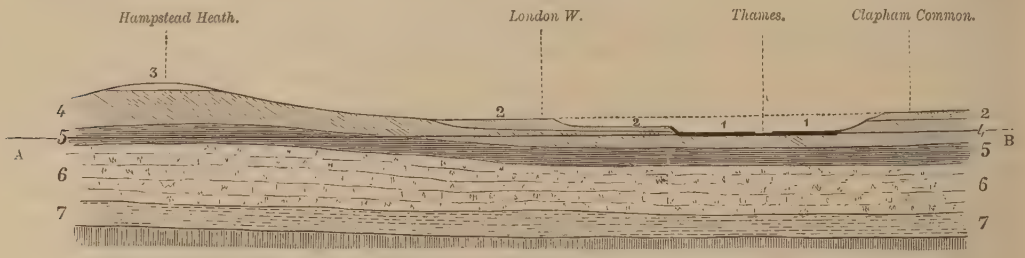


Fig. 145.—GEOLOGICAL SECTION OF THE THAMES VALLEY FROM HAMPSTEAD HEATH TO CLAPHAM COMMON.

Superficial deposits: 1, Recent alluvium; 2, Gravel. Tertiary deposits: 3, Bagshot Sand; 4, London Clay; 5, Lower London Tertiaries. Mesozoic Formations: 6, Chalk; 7, Upper Greensand and Gault. The line A B denotes the level of the sea; the dotted line from terrace to terrace shows the height to which the Gravel had accumulated, and the blank space beneath the line the hollow to which it was afterwards worn away till the Thames Valley in nearly its present form was made.

limestones reposing at heights more than 10,000 feet above the level of the sea in which they must have been accumulated.

As for Great Britain, it was during Eocene times, most likely, a portion of a great continent which stretched northward and westward to America by "way of Iceland and Greenland, while to the northward it was continuous with Norway and Spitzbergen. It extended also to the south-west across what is now the Channel to join the western parts of France." This great north-western continent, or "Northern Atlantis," Mr. Dawkins considered, existed through Eocene and subsequent Ages, offering a means of free migration for plants and animals, and it was not finally broken up by submergence until the beginning of the Pliocene Period.

* Sorby, *Edinburgh New Philosophical Journal*, N.S., April, 1857; Dawkins: "Early Man in Britain," p. 19 *et seq.*

kept by the plants and animals of the deposits formed during these comparatively brief interludes. Mr. Gardner, indeed, regards the Woolwich and Reading Beds as indicative of a much more temperate time than the subsequent strata, while the occurrence of erratic blocks in the Alpine Flysch leads to inferences regarding floating ice which may be reasonably enough entertained, though (as Lyell reminds us) we have glaciers in New Zealand close by thickets of tree-ferns and areca-palms. This fact, and the corresponding regarding "erratics" in the Southern Miocene (p. 218), may be explained without calling in so Arctic an agent as the floe or the iceberg. Finally, there must have been plains covered with pasture-herbs, since the presence of so many herbivorous mammals is only explicable on this assumption, even admitting that many of them browsed on the trees and shrubs of the Eocene jungles.

Scenic and Economic Aspects.—The world appears to have enjoyed a placid existence during most of the Eocene Age. However, towards the close of it there were violent volcanic eruptions over the northern portion of the area occupied by the old Tertiary sea. These disturbances have left their records in the sheets of basalt which poured out in the region between Antrim and the west of Scotland, in the similar basaltic outbursts through the Eocene beds of Greenland, and plants, which point to their identity of origin* with the basaltic sheets of Scotland and Ireland. In Central France, Lyell considers that there was a period when "the spacious lakes, of which we may still trace the boundaries, lay at the foot of mountains of moderate elevations, unbroken by the bold peaks and precipices of Mont Dor [Vol. I., pp. 120, 165], and the picturesque outline of the Puy de Dôme, or of the volcanic cones and craters now covering the granitic plat-

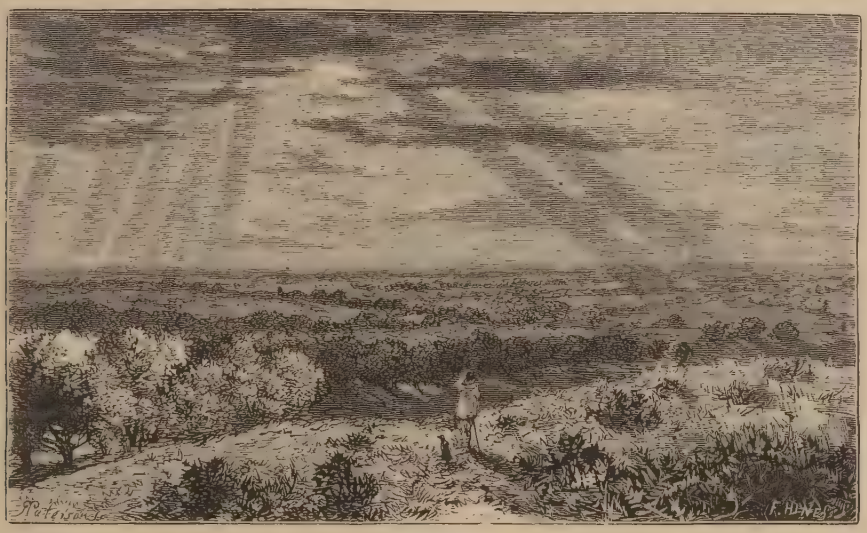


Fig. 146.—NEW FOREST, FROM BRAMBLE HILL.

in the lavas of the Auvergne district of France, and other regions of Southern Europe. These outbreaks seemed to have alternated with periods of repose, during which the lava fields got covered with vegetation, and little lakes formed, in the mud of which—witness the leaf beds of Mull between sheets of basalt and beds of tuff—their remains got embalmed. These outpourings must have been of enormous extent, for, in spite of the denudation which they have undergone—and the sea now covers most of them—the basalt beds vary in thickness from 13,000 or 14,000 feet in the Faroe Islands to 900 feet in Antrim. These are also of great thickness in Iceland, where they contain intercalated layers of lignite and form. During the earlier period of repose deltas were slowly formed; beds of marl and sand several hundred feet thick deposited; silicious and calcareous rocks precipitated from the waters of mineral springs; shells and insects embedded together with the remains of the crocodile and tortoise; the

* It must not, however, be supposed that, though the Iceland beds are of much the same age as the British ones, they got intercalated with lava and tufa at the same outburst. On the contrary, the latter is most probably of local origin, Iceland being a notoriously volcanic country. It is even open to doubt whether the beds of the Faroes are not due to local eruptions, in an area now covered by the sea, for we do not find anything similar or of the same age in the intervening Orkneys and Shetlands.

eggs and bones of water birds, and the skeletons of quadrupeds, most of them of genera and species characteristic of the [Oligocene] Period. To this tranquil condition of the surface succeeded the era of volcanic eruption, when the lakes were drained, and when the fertility of the mountainous district was probably enhanced by the igneous matter ejected from below, and poured down upon the more sterile granite." From the Oligocene Period the rise of the Alps, Pyrenees, Carpathians, and probably of the Himalayas, in part at least, also would appear to date. Hence the scenery of the Eocene—and the same remark applies to that of all the other Tertiaries—though by no means striking in itself, comprises some of the most picturesque portions of the earth. However, when the beds have not been disturbed by volcanic outbursts, or elevated by secular rise, they display, as in the Thames Valley, only a pleasing outline of a character, the tameness of which is not relieved by any notable features, either of river erosion or of freaks wrought by the weather in the stubborn clays which offer themselves to the rain and frost (Fig. 145).

From an agricultural point of view the Eocene is not attractive, though, owing to its proximity to several great cities and populous centres, it has received more attention than under other circumstances it would have obtained. In the vicinity of London, where it is often overlaid by vegetable mould, sand, and gravel, to a considerable depth, it is, indeed, a highly cultivated region, though there are other tracts—the Bagshot Sands, for example—which are so utterly unfruitful that they still remain in a condition of Nature. It may, indeed, be affirmed in general terms that where we find—as we do in the county of Surrey—many commons, the exemption of these tracts from cultivation and enclosure was due mainly to the poor soil of which they are composed, scarcely one of those which have escaped annexation being worthy of the plough and harrow. The New Forest in Hampshire is a case in point. The popular tale is that this tract was turned into a hunting-ground by William the Conqueror. However, without venturing to dispute this tradition, or to imagine that the monarch, who "loved the tall deer as if he had been their father," was troubled with any scruples regarding the uses to which he put the English soil, it is impossible for a geologist not to agree with Sir Andrew Ramsay, that the wet and unkindly clays and gravels of that portion of Hampshire could never have produced a more profitable crop than that which for ages it has supported. It is certain that it was at no period a populous or a cultivated country, and in all likelihood in the Conqueror's day, as in ours, it was simply a grazing ground for cattle, *plus* the wild animals then abundant in all parts of England (Fig. 146).

The economic products of the Eocene are neither numerous nor valuable. From the latter point of view, amber (p. 205) is, perhaps, the most notable,* though possibly, owing to the proximity of London, the brick-making industry of the Thames Valley is a source of greater profit. The "London Clay" is, however, rather too stiff for that purpose, the "plastic clay" of the Woolwich series being preferred. Lignites are found in many Eocene beds (pp. 200, 203, 205), and it is doubtful whether any of the lignites of Washington Territory (United States) and the opposite or Juan de Fuca Strait of Vancouver Island (where, more than twenty years ago, the writer found them cropping out in various places†) are of much, if any, older date. Gypsum occurs at Montmartre in the Paris Basin, as a granular or crystalline rock, and for more than a century the Bovey Tracey Basin has been worked for potters' clay and pipe-clay (kaolin, p. 204), as much as 46,000 tons being shipped in some years, besides what is used in the neighbouring pottery, the

* In "Science for All," Vol. IV., p. 213, Mr. Rudler has given a good account of this substance, to which the reader is referred for further details. See also Pierson: "Elektron" (1869), and Dawkins: "Early Man in Britain," pp. 417–422.

† Brown, "On the Geographical Distribution and Physical Characteristics of the Coal Fields of the North Pacific Coast" (*Transactions of the Geological Society of Edinburgh*, 1870). It is proper to add that recent discoveries have greatly modified or extended many of the conclusions at which the writer then tentatively arrived.

fuel for which is supplied by the associated beds of brown coal or lignite. The Calcaire Grossier of Paris is a good building stone, and the Calcaire siliceux of the same locality, and similar beds in the Eocene of the Southern United States, supply the material for the well-known "burr" millstones. The Nummulitic and other limestones are also employed as building stones, as are the "grey wethers," "Druid stones" or "Sarsen stones" which often strew the surface of the Chalk downs around the London Basin. They are blocks of hard silicious grit, and belong, in part, to the Woolwich and Reading series, though some of those found on the London Clay may have been derived from the Bagshot Sands. At one time they were much more numerous than they are nowadays, their continual utilisation as building stones, road metal, gate-posts, paving stones, and for other local purposes, having gradually diminished the number of those scattered over the chalky downs of Wiltshire, and especially those of Marlborough, where they are still abundant enough to attract attention. Many of them are from twelve to fifteen feet across, and sometimes four feet thick. Hence the uses to which they have been applied from the earliest times. For instance, the great monoliths out of which Stonehenge (Fig. 147), Avebury, and other "druidical" monuments in Wiltshire, have been constructed were not brought from a distance, but are simply the "grey wethers" of the neighbourhood.* Mr. Prestwich is inclined to regard these isolated blocks in the Eocene sands and clays as due to cementation of the previous loose sands by the soluble silica set free when the kaolin which they hold in abundance was formed from the old decomposing granitic and gneissic areas formerly stretching to the west and south-west of this Tertiary district. The cementation—and the same remark applies to the isolated blocks known as "Hertfordshire pudding-stones"—is sometimes so complete that "the grains of sand seem as though fused and run together, and flint pebbles are so completely incorporated with the matrix that the jointing of the beds and the fracture caused by a blow run equally through both the matrix and the enclosed pebbles."

Salt, we have seen (p. 161), is found in Tertiary beds which may possibly be of this date, and the lowest or Salton bed of the Coralline Crag (which rests on the London Clay) is worked for its phosphatic nodules, though, not unlikely, many of the bones of various animals which it contains (p. 221) are derived from beds of older date.

* The smaller ones—or "blue stones" (Fergusson's "Rude Stone Monuments," p. 92)—which are mostly of igneous origin, must, however, have been conveyed from Cornwall, Wales, or even from Ireland.

Fig. 147.—STONEHENGE.

CHAPTER XII.

The Cainozoic Rocks: Miocene and Pliocene Systems.

The Miocene not represented in the British Islands—Where seen Elsewhere—France—The Faluns—Swiss Molasse—Œningen Deposits—The Vienna Basin—The Russian Deposits—The Italian Deposits—The Pikermi Beds of Greece—Malta—The Antipodes—The Siwalik Beds of India—The Miocene Deposits of the Western States and their Mammalian Remains—The Arctic Miocene Beds—The Life of the Period and its General Characteristics—Physical Geography of the Age—General Character and Distribution of the Pliocene Beds—Classification—The Coralline Crag—The Red Crag—The Norwich Crag—The Chillesford Beds—The Forest Bed Group—The Fossils of the latter—The Pliocene Flora and Fauna—Herbivorous Quadrupeds—The Ancestry of the Horse—Physical and Economic Features of the Pliocene System—Volcanoes—Climate of the Period—Approach of Man—Signs of his Coming—etc.

Until very recently it was held that the leaf-beds of Mull, Skye, Antrim, and Bovey Tracey, represented the Miocene. But these deposits being now generally assigned to an earlier date (p. 204), the "more recent" system has no member in the British Islands, unless, indeed, the sands found in a cavity in the Chalk downs above Lenham in Kent (and which, on account of the accident of their position, have escaped the denudation which has overtaken the rest of the beds) be doubtfully referred to that Age. On the Continent of Europe, however, and in other parts of the world, the Miocene System is extensively developed (Fig. 148).

In the west of France they constitute the deposits containing the bones of terrestrial animals mingled with those of marine organisms, which are known as the "Faluns" of the Touraine and of Brittany. Of the fossils from 14 to 32 per cent. (varying in different Orders) are still living, the majority of the shells belonging to species now found in the Mediterranean, on the West Coast of Africa, and in the vicinity of the Atlantic Islands, like Madeira and the Canaries. In Belgium the system is less sparingly developed, the Black Crag near Antwerp being the most notable of the Miocene beds of Flanders. In and near Barcelona, the southern and central parts of Spain, in the Tagus valley, and in Madeira and the Azores, we find beds of this Age; while the only parts of Germany in which they occur are the Mainz Basin, Mecklenburg, Schleswig-Holstein, Hanover, Oldenburg, Westphalia, etc., where they constitute the Sands of Stettin, and the Sandstones of Bokup, Melbeck, Bersenbrück, and Holstein.*

In Switzerland we find an immense development of Miocene in the shape of a great thickness of soft sandstones, marls, limestones; occasionally conglomerates, which are known as the Upper Molasse, are exhibited, especially at Œningen on the Lake of Constance, twelve miles east of Schaffhausen, where plants† of American and European types abound, commingled with others closely allied to forms found in Africa, Asia, and Australia, in addition to a fauna so abundant that out of the thin laminated sandstones, marls, and limestones, which seem to have been deposited in the waters of some deep and tranquil lake, the late Dr. Heer‡ described 826 species of insects, 28 spiders, 7 crustaceans, 4 mollusca, 32 fresh-water fishes, 12 amphibians and

* Von Koenen: "Das miocän norddeutschlands" (1867); "Beitrag zur Kenntniss der Mollusken-Fauna des norddeutschen Tertiärgebirges" (1867), and in connection with the above his "Das marine Mittel-Oligocän norddeutschlands (Système Rupelien Dum., Etage Tongrien K. Mayer) und seine Mollusken-fauna" (1868—1869).

† "Flora tertiaria Helvetiæ" (1855—1859).

‡ "Die Insekten-fauna der Tertiär-gebilde von Œningen und von Radoboj in Kroatien" (1848—1853); "Fossile Hymenopteren aus Œningen und Radoboj" (1867), and his more popular "Die Urwelt der Schweiz" in its English translation, by W. S. Dallas (1876).

reptiles, 6 birds, and 6 mammals, in addition to 475 species of plants. As might be expected from the dense vegetation among which they lived, wood-eating beetles are particularly abundant. A *Dinotherium* (*D. giganteum*), the *Mastodon tapiroides*, and, in addition to a monkey, and other species, a fox (*Galecynus œningensis*), which shows kinship to the civet, are among the spoils of the and estuarine beds; and (*c*), an Uppermost or Tortonian stage, in which the typical plants and animals of the Œningen Molasse are seen to perfection.

The Tertiary beds of the Vienna Basin (Fig. 149), which stretched from the Carpathians to the plateau of Moravia and Bohemia, and on the south is shut in by the Eastern Alps, contain some important Miocene strata,

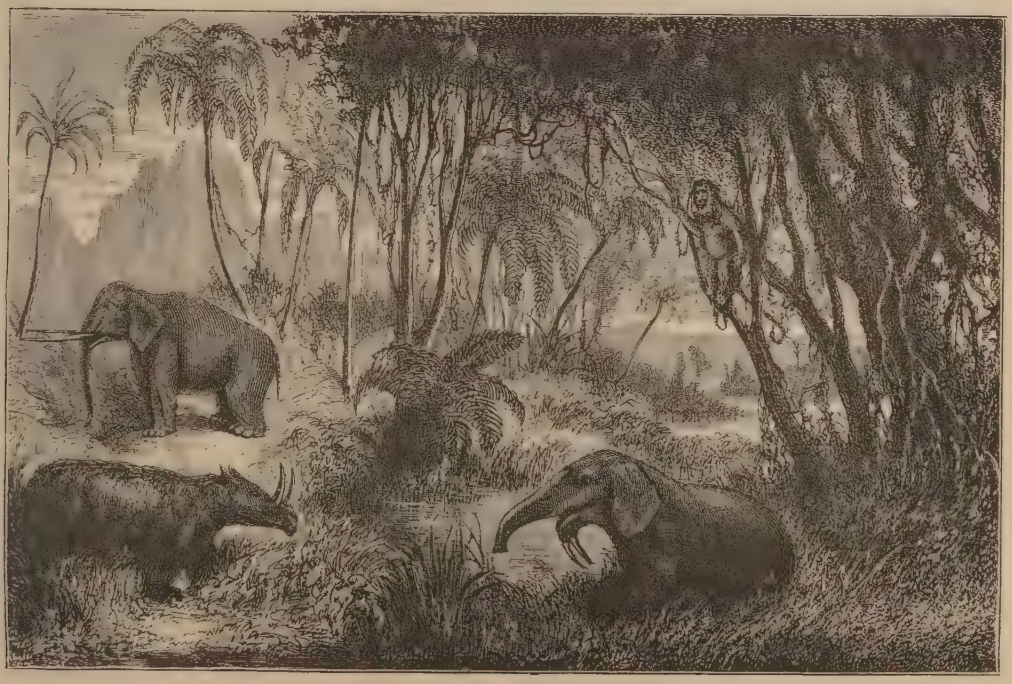


Fig. 148.—IDEAL LANDSCAPE OF THE MIOCENE AGE.

Œningen beds. It is also interesting to note that there occurs a huge salamander (*Andrias scheuchzeri*), which was at one time thought to be a human skeleton, and the subject of a treatise to that effect (p. 29). These Swiss Miocenes fall into three divisions:—(*a*), a Lower or Mainz (Mayence) stage, fresh-water beds, with a marine one in the middle of them, containing many palms, figs, acacias, pines, with rhinoceri, crocodiles, etc., the vegetation being of a markedly North American facies; (*b*), a Helvetian stage, composed of marine stretching in places to a depth of fully 1,000 feet. These deposits may be described as sands, sandstones, clays, limestones, and marls, of a very variable character, though the lower portion of them is marine, and the upper more inclined to a brackish type, showing that the ancient inland sea or salt lake in which they accumulated had, before the close of the Period, got invaded by rivers, or had got so fresh that the old types could no longer flourish in its waters. It may be divided into three great stages: (1), The

Lower or Mediterranean, the most conspicuous member of which is the highly fossiliferous limestone known as the Leithakalk, containing 900 species of mollusca, with corals, polyzoa, cephalopods, crustacea, and other animals, mingled with a nullipore or calcareous seaweed, like corallines (the *Lithothamnium ramosissimum*), and *Amphistegina haueri*, a foraminifer, which between them constitute the greater portion of some beds (Vol. I., p. 55). The "Tegel," a blue clay full of shells, the marl of Gainfahren, etc., the sand of Pötzleinsdorf, the sandstone of Sievering, etc., are stones and sandy clays, indicating by their contained fossils a half-brackish character. These fossils are, for the most part, shells, which exhibit affinities to those of the Black Sea, and very little with those of the tropics, or even of the Mediterranean. The plants are also, to a large extent, American, though palms are entirely absent. It comprises a number of sub-divisions, *e.g.*, the Hernals Tegel, which contains the bones of seals, dolphins, sea-cows, and whales (*Cetotherium*), with numerous mollusca; the Sarmatian or Cerithium sand (so called from the notable number

Fig. 149.—SECTION THROUGH THE VIENNA BASIN.

Cr., Crystalline rocks of the Leitha Mountains; V.S., Vienna Sandstone; I, Mediterranean Stage Beds; *a*, Conglomerate; *b*, Leithakalk; *c*, Marine Sand and Tegel; II., Sarmatian Stage Beds; III., Congerian Stage Beds.

among the various subdivisions of the stage, and are considered to mark different conditions of deposit during the time the Vienna Basin was in this state. Brown coals are found in it, just as similar accumulations have formed in the Oligocene ones immediately below. The fauna is inclined to be tropical, the flora being akin to that of India and Australia, while the mollusca are many of them still living in the Mediterranean or on the western coast of Africa. The flora preserved in some fresh-water beds comprises various palms and conifers (including *Libocedrus* and sequoia, both American genera, the latter essentially Californian, p. 201), figs, oaks, laurels, cinnamons, mimosas, maples, walnuts, varnish trees, acacias, myrtles, and among other Australian plants the proteaceous genera *Banksia* and *Dryanda*. In the lower part of this stage are found the bones of several mammals. These also occur in the west division, though it is not until the Uppermost stage is reached that mastodons, rhinoceri, etc., appear in abundance.

(2) The Sarmatian stage comprises the middle portion of the beds, consisting of sand- of *Cerithium pictum* and *Cerithium rubiginosum* in it); and the Upper Sarmatian Tegel, or Mussel Tegel, with *Tapes gregaria*, etc., which attains a thickness of over 300 feet, and is drilled with the artesian wells, which yield a considerable portion of the Vienna water supply (Vol. I., p. 269).

Lastly, (3) there is the Uppermost stage* of all, comprising brackish or fresh-water clay from 300 to 400 feet thick, which may be called the "Congerian," from the number of shells belonging to the genus *Congeria* (*C. subglobosa, C. spathulata, C. partschi, C. triangularis*) found in it, along with *Melanopsis vindobonensis, M. pygmæa*, etc.

In the middle of the three sections into which it has been divided are found the bones of various great mammals, all of extinct species, such as *Mastodon longirostris* (Fig. 150, A), *Dinotherium giganteum* (Fig. 150, B), *Hippotherium gracile, Aceratherium incisivum, Tragoceras* (an antelope), and various vanished species of stags, swine, etc. In the uppermost (the Belvedere beds) there

* In some classifications this stage is referred to the Pliocene.

are found leaves and twigs of a conifer (*Thujoxylon juniperinum*), birch, *Carpinus* (hornbeam), *Fagus* (beech), *Tilia* (lime), etc., besides such types as Sequoia, Liquidambar, and other forms characteristic of Asia Minor, the Caucasus, Central and Northern Asia, Japan, Western America, and the Himalayas.*

These are the best-known localities of Miocene deposits in the Old World. They have, however, a much wider distribution. In Russia they stretch from Volhynia and Podolia away to the Caspian and the Sea of Aral, the beds containing, in addition to a fauna very similar to that of the Vienna Basin, some forms still living in the Caspian. In Italy they extend under the plains at the foot of the Alps to South Italy, Sicily, and the neighbourhood of Rome, the beds in some places being from 10,000 to 12,000 feet thick. At Pikermi in Greece (Attica) there are Miocene beds† containing mammals intermediate in character between those of Europe, Asia, and Africa. Some of these are of large size, antelopes with curious horns, large monkeys, clumsy rhinoceri, great wild boars, mastodons still more gigantic, the giraffe-like *Helladotherium*, etc.; and the probabilities are that in the area now dotted with the "Isles of Greece" an extensive plain stretched from Mount Pentelicus to the shores of Asia Minor, thus commingling the fauna of Europe and Asia—an assumption to which the presence of animals closely akin to, and in some cases identical with, the Greek ones in Miocene beds in Persia gives strength. This Attic plain seems to have existed until the depression which ushered in the Pliocene Period covered it with the sea, as shells of that Age at Raphina abundantly prove.‡ In Transylvania Miocene beds are found, while in Africa, Algeria, Egypt (including the district with silicified trees in the neighbourhood of Cairo), and the Soudan may be mentioned as countries in which deposits of that Age occur. The island of Malta consists almost wholly of Miocene beds, containing many sharks' teeth, sea-urchins, and a sea-cow (*Halitherium*),§ though we have no proof that until the Pliocene Period this island formed a portion of the African continent on one side and of Sicily on the other, while Morocco was united with Spain, thus dividing the Mediterranean into two great lakes. In Australia we find the Miocene cropping out in the cliffs near Portland in the colony of Victoria, but the beds there do not seem to have had any connection with those of New Zealand, in the Lower Miocene of which, Sir James Hector tells us, 55 out of 110 species are still living, while in the Upper beds out of 120 there are only 25 extinct, the recent ones all living in the neighbouring seas.

The most remarkable of all the Miocene beds of India are those of the Siwalik Hills, which have yielded such an extraordinary number of extinct animals — monkeys, elephants, deer, lions, giraffes, camels, ostriches, cranes, a tortoise so enormous that it might be the fabled one on which the world-bearing elephant stood,‖ in all ninety-three species, comprising forty-eight genera. Among the most notable of the Siwalik fauna must have been the *Sivatherium* (Fig. 151), a ruminant allied to the antelopes,¶ though resembling the reindeer, but with four instead of two horns, which also was the number allotted to the *Brahmatherium*.

In North America the best known Miocene deposits are those of the States of New Jersey,

* Hörnes and Partsch: "Die Fossilen Mollusken der Tertiärbecken von Wien" (1851-70); v. Ettingshausen: "Die Tertiärfloren der Oesterreischen Monarchie" (1851); etc., etc.

† These are by some geologists declared—erroneously, we believe—to be Pliocene.

‡ Gaudry: "Les Enchaînements du Monde Animal," p. 258, and generally his "Animaux fossiles et Géologie de l'Attique" and "Les Animaux fossiles de Pikermi" (1866).

§ Leith Adams: "Wanderings of a Naturalist in India, etc.," p. 216.

‖ Falconer—to whom, in company with Cautley and (still more recently) Lydekker, we are indebted for nearly all our knowledge of these beds—estimated it to be twenty feet long and seven feet high. It ought to be added that, though Falconer regarded these beds as Miocene, other geologists maintain them to be Pliocene (Falconer and Cautley: "Fauna Antiqua Sivalensis," 1845-49; Medlicott and Blanford: "Geology of India," p. 577; etc., etc.).

¶ Dr. Murie has suggested the strong probability of this gigantic ruminant being very nearly akin to the little prongbuck (*Antilocapra*) of Western America.

Delaware, Maryland, Virginia, the two Carolinas, Georgia, the Upper Missouri, Colorado, Utah, Oregon, and the neighbouring Territories. In those to the east of the Mississippi there are not many features of special interest, except that near Richmond there is a deposit of diatoms 30 feet thick (p. 203), while near Monterey in California there is one 50 feet thick. The Eastern and Western beds show considerable difference in their species, while the latter contain another of those extraordinary collections of mammals with which the West has already familiarised us when considering earlier Formations. The "Brontotheridæ" of Marsh were mammals of great size, whose heads were armed with a pair of powerful horns. In *Diceratherium*, two rhinoceros-like horns were placed transversely. *Oreodon* was a mammal which combined in itself several of the characteristics of the camel, the pig, and the deer, though camels, wolves, lions, bears, beavers, hogs as huge as living rhinoceri, a monkey, and *Mesohippus*, *Miohippus*, and *Anchitherium*—three-toed horses—also occur, the species, and in most cases the genera also, not being at present represented on the earth. In several instances the families have ceased to exist, though in many of these Western animals we see the "head-marks" of others with which we get more familiar the nearer we approach our own times. It is interesting to note that in these deposits America, even then progressive, possessed several genera which in Europe did not appear until a much later period. The beds in which Leidy, Marsh, and Cope found these notable contributions to the history of the Old World attain a thickness of from 1,000 to 2,000 feet, and seem, like so many of the other Tertiary deposits, to have been accumulated in those lakes which — even until a comparatively recent geological date —covered much of the Western territories which are now dry land (Vol. I., p. 326).*

The only other Miocene beds which we need notice are those of the Arctic Regions. These have only been found in Spitzbergen and in Grinnell Land on the shore opposite North Greenland. At one time deposits on or in the vicinity of Disco Island in the last-named country were regarded as belonging to this division. But, as we have seen, further research has divided them between the Cretaceous and the Eocene. It is, therefore, within the limits of probability that when the Spitzbergen and Grinnell Land strata are more fully investigated, they may be assigned to the latter Period. Meanwhile we can only describe them as Miocene. From those of Spitzbergen about twenty-five species of plants —alders, hazels, poplars, limes, birch, and sequoias—have been obtained, the general character of the flora indicating a rather

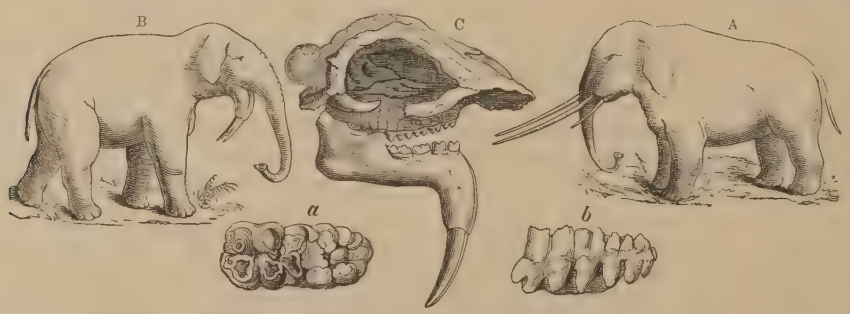


Fig. 150.—MIOCENE AND PLIOCENE MAMMALS.

A Mastodon longirostis (*restored*)—*a*, Molar of same from above; *b*, from the side. B, Dinotherium giganteum (*restored*)—*c*, Skull of same.

* Marsh's "Gigantic Mammals of the Order Dinocerata" (*United States Geological Survey*, 1883-84, pp. 243–302). His monograph on the "Dinocerata" (1884) contains a complete account of these animals, with restorations of *Dinoceras mirabile* and *Tinoceras ingens*.

colder climate than the Eocene of Greenland, a fact which may be explained by the more northern position which it holds, apart from the circumstance of the Miocene Age being one in which a lower temperature prevailed than in the early Tertiary Period.

The Grinnell Land deposit is still more remarkable. It is situated on the shores of Discovery Bay in lat. 81°, 45′ N., and was discovered by the officers of H.M.S. *Discovery*, during the Arctic Expedition of 1875–76. Of the twenty-six species of plants obtained, six are European Miocene forms, four are American (Alaska and Canada), seventeen are common to Spitzbergen, and eight agree with species from the Greenland beds now pronounced to be Eocene. The climate seems to have been cooler during the time they lived than that of Eocene Greenland, cypresses and other conifers being common, and among other species we find a *Taxodium* (*distichum miocœnum*), very common in the European Miocene beds, and a water-lily (*Nymphœa arctica*), which tells of the placid waters in which the deposits were laid down.* That there must have been a rank vegetation at this spot, is evident from the fact that at Watercourse Bay a coal bed 20 to 25 feet thick was found; so that, in times which are geologically very recent, a flora as temperate as that of California flourished within 500 miles of the North Pole, in a region which is now so cold that not even a shrub can exist in its frozen soil.

Life of Miocene Times.—The most striking general characteristic of the Miocene fossils is their rapid approximation to modern types. A large percentage of the shells (pp. 199, 215, etc.) is identical with those still extant, and many of the plants are difficult to separate from their nearest allies now living. The mammals seem, however, not to have progressed so rapidly as the other forms of life, for though not a few are closely allied to modern species, and several belong to living genera, some of them are as wide apart from the quadrupeds of this Period as the

Fig. 151.—SIVATHERIUM (RESTORED).

* For some discussion on the probable age of these beds, see *Quarterly Journal of the Geological Society*, 1878, pp. 568–70.

reptiles of the Lias from those of the African swamps. What is more, that differentiation or separation of groups which we find so general nowadays, did not prevail, for a number of the species had still, as in former Periods, characters which have long ceased to be combined in any one species or genus, family or order (p. 216). The various beds are not only extremely irregular or patchy, but they are no longer so sharply cut off from each other by the presence of characteristic species as those with which we have had to

that date, his conclusions still hold good—mentions, that of the newer Tertiary plants (Fig. 152) which he had examined from the beds of middle Europe, 83 found their nearest allies in the Northern and 103 in the Southern United States; 40 in tropical America; 6 in Chili; 137 in the milder or more Southern parts of Europe; 85 in tropical Asia; 25 in the Atlantic Islands; 26 in Africa; and 21 in Australia.

But even here occur traces of the presence of floating ice. For, unless on the assump-

Fig. 152.—MIOCENE AND PLIOCENE PLANTS AND INSECTS.

1, Sabal major (fan palm); 2, Cinnamomum (cinnamon tree); 3, Laurus princeps (laurel); 4, Glyptostrobus (cypress); 5, Taxodium dubium (swamp cypress); 6, Planera; 7, Myrica; 8, Acer trilobatum (maple); 9, Rhynchites dionysus (beetle); 10, Myrmica tertiaria (ant).

deal in the older Formations. Thus the collation of the different deposits, and their reference to a particular place in the classification adopted, is so difficult that wide differences exist regarding the relative position of various strata. These differences (several of which have been indicated) do not, however, in any way affect the broad conclusions arrived at from the study of the fossils in the critical layers. And so far as climate was concerned, the species which flourished in Miocene times are so nearly akin to those of modern days, that we are quite justified in inferring that the tropical climate which prevailed during the Eocene Period held true of the earlier Miocene also, the cooler age not coming until near the close of the times of which we speak. Heer writing in 1860*—and though he examined many species after

* "Ueber das Klima und die Vegetationsverhältnisse des Tertiärlandes" (Winterthur, 1860).

tion that they were carried by this agency, it is difficult to account for the erratic blocks which we find in the Miocene of Italy, France, and Spain. These blocks, Mr. Dawkins, however, suggests, may have been conveyed simply on the surface of glaciers, just as in New Zealand such upland rivers of ice protrude themselves into a region where tree-ferns and areca-palms grow (p. 208). A study of the localities covered by Miocene beds shows that in this age, unless there has been great denudation, the British Islands and most part of the North of Europe were dry land, though much of what is now the middle and south of the Continent consisted of a series of lakes, extending eastward into Asia, with what are now considerable mountain ranges appearing as islands in this watery archipelago. The Alps had, however, by this time risen appreciably, and the elevation of the chains went on during most of the

Miocene Period. As a rule, however, the Age was a placid one, volcanic rocks intrusive or intercalated being rare or unknown. Hence, except where the beds lie on the flanks of mountains which have risen since their deposition, or are fantastically weathered, Miocene scenery is as tame as that of the Tertiary Epoch generally.

The economic products of the Miocene beds are also few. They do not yield any notable building stones, and the lignites associated with them are of very indifferent quality. Indeed, if we except the "Faluns"—a term now applied to a series of French beds, but which was originally meant to describe loose marly or shelly sands, spread like the "crag" of Suffolk over the fields as a fertiliser—it is difficult to recall any special economic value which the Miocene beds possess. Before so many of the deposits originally regarded as of this Age were transferred to the Eocene, they would have contributed to the world's wealth in a greater degree. As it is, Mr. Gardner has left them very poor.

Pliocene System.

The irregular beds which go under this name are poorly developed in Great Britain, and nowhere are all the members of the series present, while the deposits themselves are usually "lenticular"—that is, lense-shaped—or, in other words, they do not maintain the same thickness for any distance, thinning out at either end. Altogether, they do not much exceed 120 or 130 feet in depth, and consist for the most part of sands, clays, and gravels containing the very large percentage of shells and other remains identical with living forms which has given them the title already explained. But on the slopes of the Apennines they have accumulated to the thickness of several thousand feet, and they are also found in Sicily and other parts of the Mediterranean Basin. In addition, Pliocene deposits full of the remains of whales and seals are seen in the neighbourhood of Antwerp, while in various parts of the west and south of France, and in the Rhone Valley as far north as Lyons, there are patches of Pliocene strata. Most of these have yielded to the palæontologist bones of rhinoceri, mastodons, tapirs, and elephants, though all of extinct species, besides ample remains of the plants which flourished during the Period. In the central districts of Europe the beds of the Mainz Basin contain plants of an American type and bones of the *Dinotherium*, *Anthracitherium*, etc., and, in the opinion of some writers, the Upper Beds (p. 214) of the Vienna Basin, are the only other notable Pliocene beds of Europe. In North America, in strata of the Upper Missouri region, usually regarded as Pliocene bones of numerous vertebrate animals have been discovered. In the Lower beds these consist of the oldest known camels—animals not natives of the New World within historical periods, viz., *Protocamelus* and *Homocamelus*—horse-like animals like *Protohippus* (Fig. 156, D), *Pliohippus* (Fig. 156, E), and *Merychippus*, besides the mastodon, an ox, a tapir-like beast (*Tapiravus*), etc.; while in the Uppermost appear a true tapir (Fig. 155, A), an elephant, and a horse as large as the living species. In addition, there were an eagle, a cormorant, a crane, and a tiger larger than that of Asia.* In Australia, in the rich gold-bearing deep leads, often buried under outpourings of lava, are found various fossils referred to Pliocene times—for example, the *Diprotodon* and the *Nototherium*, both marsupials, though the one seems to have been as large as a rhinoceros, while the other (of which three species are known) has been likened to a tapir. There were also kangaroos twice as big as any of the modern species, marsupial lions and hyænas, and a near ally of the Tasmanian devil, besides a species of the gigantic *Dromornis*, of which the emu—a bird which figures in the arms of New South Wales—may be regarded as the nearest living relative. The Siwalik Beds of India and the Pikermi ones of Greece, which have been described as Pliocene, we have already referred to the Miocene (p. 215), though in the interval between these two geographical

* For a section illustrating the succession of vertebrate life in America, see Marsh in *United States Geological Survey Report* for 1883–1884, p. 253, Fig. 37.

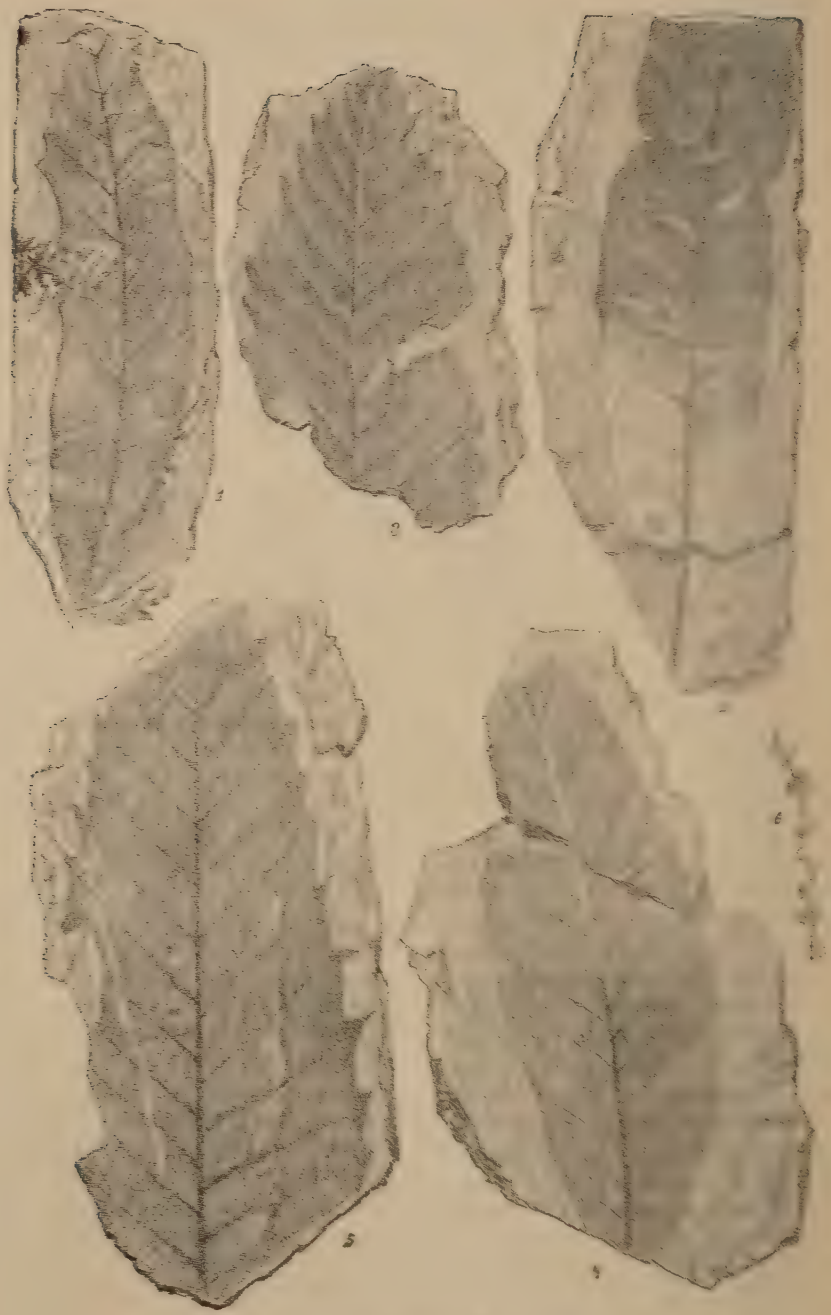


Fig. 153.—TERTIARY SPECIES OF CHESTNUT.

1, 2, Leaves of Castanea atavia Ung.; 3, 4, Leaves of C. ungeri Ett.; 5, Leaf of C. kubinyi Ett.; 6, Cutkle of C. atavia Ung.

…s we find representatives of the Plio- … the Aralo-Caspian beds (around the … Aral, and Azof Seas), which contain …any of them identical with species …he Caspian, and evidently the life of …one sea which stretched over much of …Asia, leaving in our day the various …seas or lakes of that region as the …y diminishing (Vol. I., p. 326) remains …nce extensive sheet.

…sification.—The following is the general …ment of the British beds, with their …equivalents, so far as these can be …ned, though it is seldom that any …extra-European ones can be referred …doubt to the sections which we shall …describe. It is, indeed, questionable …some of those of Australia and India …be representative of divisions not …recognised by geologists.

*…e Coralline, or White Crag,** is limited …places in Suffolk, where it consists of …nds and flaggy limestone, in places …composed of the animals known as …which, from the first describer of …cks supposing them to be corals, gave …their best-known name. The other …are equally numerous, the whole …cing to fully 1,100, so far as shell-fish …eir allies the polyzoa are concerned. …ese the majority belong to existing …86 per cent. of the mollusca being …cing, though more than one-half are …os of the Mediterranean. There are …w fishes preserved in the Coralline …nd of land mammals, a mastodon, a …ros, and a stag, are the principal forms. …tacea are not infrequent, a *Ziphius*†

…ag" does not in this case admit of its ordinary …; it is a local name for certain shelly sands used …k as fertilisers.

…group of whales to which *Ziphius* belongs is …e in our seas, the ordinary beaked whale, or bottle-…(*Hyperoodon rostratum*), being the only common …But they have survived in numerous forms in …which surround the Australian continent, ex-…from the Cape of Good Hope on one side to New …on the other. The history of *Ziphius* and its …*Mesoplodon* of the Belgian and Suffolk Pliocene is …more that of the marsupial mammals, of *Ceratodus* …and of *Terebratula*, and of numerous other

having been found near Sutton, in Suffolk, and, among other remains, the ear-bones of another species of whale occasionally come to light, while, if the marine sands of the neighbourhood of Antwerp are, as some of them are considered to be, equivalents of this Formation, it is eminently rich in the remains, not only of sharks and other fishes, but of seals and whales of many species.

(2) *The Red Crag* is about forty or fifty feet thick, and derives its popular name from the sands of which it is composed being usually coloured deep red or brown by ferruginous matter. In many places it is thickly studded with shells, either entire or broken, and as many of them and the other fossils are worn, it seems not unlikely that they were derived from the detrition of pre-existing beds, most probably of Miocene Age, which also seem to have been the source of some of the ear-bones in the basement-bed of the Coralline Crag. About ninety-two per cent. of the shells belong to species still living. Of mammals, *Hipparion*, *Halitherium*, *Hyænarctos*, and other Miocene forms occur, though, from the reasons already mentioned, it is suspected that they were not the fauna of this, but of the previous Age. The bulk, however, of the mollusca indicate that the seas in which they lived were gradually getting colder, just as the Age which succeeded was colder still.

(3) *The Norwich* or *Mammaliferous Crag* is a much newer deposit than either of the two mentioned. Like all of the Pliocene deposits of England, it is extremely local, but is well exhibited in the pits at Thorpe and Bramerton near Norwich, where it overlies the Chalk without the intervention of the older beds. In that locality it consists of loose sands, loam, and gravel, in detached patches from two to thirty feet in thickness, the contained fossils being a mixture of marine and fresh-water types indicating that the deposit was formed in an ancient estuary. Some of these remains are shells, of which not more than 6·5 per cent. are extinct forms;

forms.—Flower, *Transactions of the Zoological Society*, Vol. VIII., p. 203.

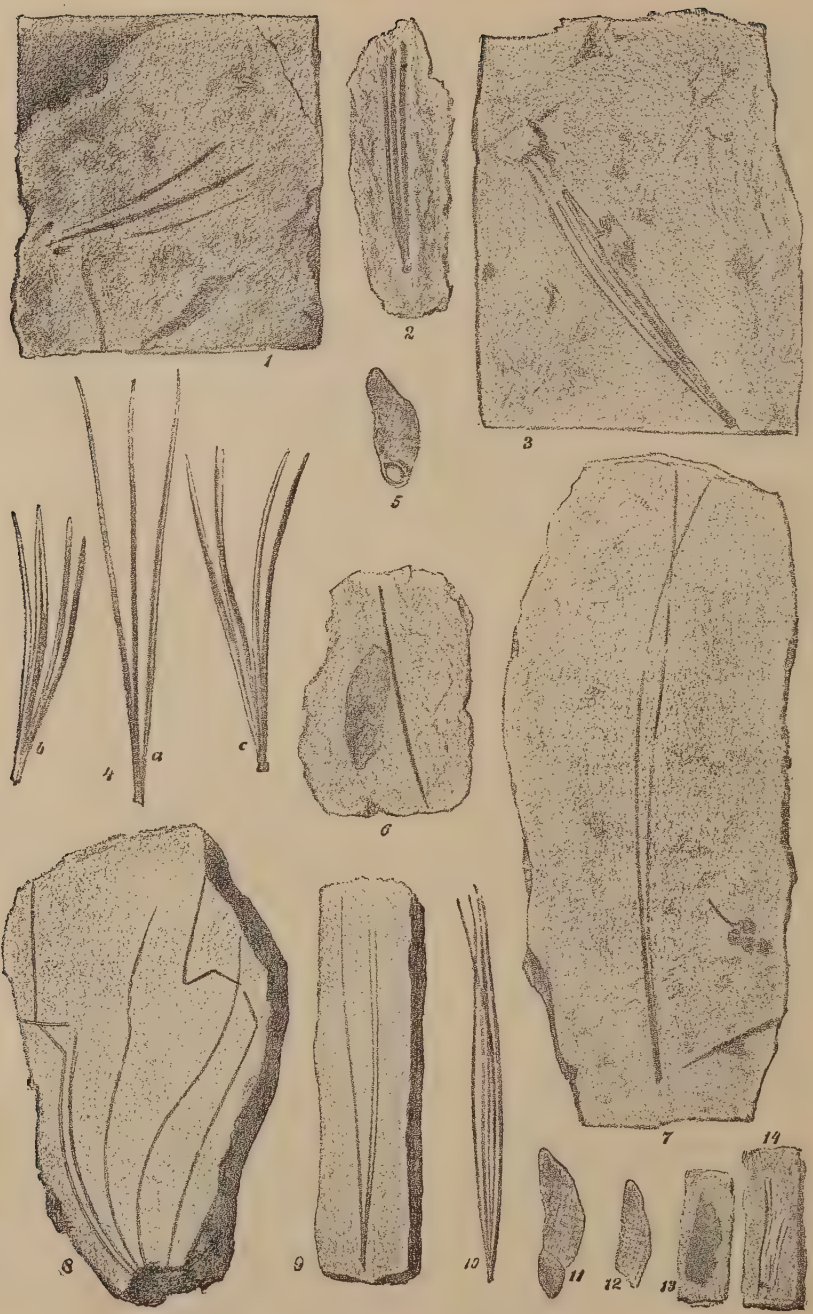


Fig. 154.—TERTIARY SPECIES OF PINE.

1, 2, Pinus præ-cembra Ett.; 3, P. palæo-cembra Ett.; 4, *a*, *b*, *c*, P. Cembra L. (living form) P. laricio Poir. (seed); 6, P. palæo-laricio Ett. (seed); 7, (Leaf); 8, 9, P. palæo-strobus Ett. (leaf); 10, P. strobus L. (the living white pine); 11, 12, (seeds); 13, 14, P. palæo-strobus Ett. (seeds).

and of the living forms, a good many begin to be types now found chiefly in colder seas than those of Great Britain. In addition, we find in the Norwich Crag the bones of extinct bears, oxen, horses, elephants, hyænas, stags, and other mammals, the abundance of which has suggested the name of "mammaliferous crag" for this deposit.

(4) *The Chillesford Beds* are sands and clays, ten to twenty feet thick, found near Chillesford in Suffolk, containing marine remains, which indicate not only a deeper but a colder sea than that in which their predecessors existed. Of the shells, fully two-thirds are identical with species still living in the seas of Greenland and Spitzbergen, such as the Greenland cockle (*Cardium grœnlandicum*), *Lucina borealis*, *Cyprina islandica*, and other forms, which, if not peculiar to the Northern Ocean, are much more common there than in British waters.

(5) *The Forest Bed Group* may be regarded as the topmost member of the Pliocene, the deposit which was last laid down before the gradually approaching great ice sheet reached these latitudes, and killed off the swarm of tropical and semi-tropical plants and animals which still lingered in our seas and on our shores in company with others of a more boreal type. This advent is indeed clear in every bed we examine. In the Bure Valley and Weybourne Crags we see a more Northern type of the Norwich Crag (Prestwich), if, indeed, the Chillesford Beds are not simply to be regarded in this light, while some sands and gravels found under the Boulder Clay on the coast midway between Aberdeen and Peterhead in Scotland, though far dissevered from the Norfolk beds, are not unlikely the records of a still more frigid period immediately preceding the great ice Age.*

The Forest Beds consist of a variety of thin silts, clays, and sands, the bottom members of which are either fresh-water or estuarine, while the upper ones are marine. They derive their name from the fresh-water beds containing a layer of peat, in which the rootlets of the trees which grew on the surface are still standing, and even penetrating into the clays beneath, as may be seen at low water on the shore at Bacton and Happisburg. The trees consist of the Norway spruce (which has never been a native of these islands within the memory of man), oaks, yews, spruces, beeches, sloes, with numerous marsh plants, all of species still common in the neighbouring district of Norfolk (Figs. 153, 154).

Associated with the forest beds is a layer which, from the number of extinct elephant bones which it contains, has been called the "Elephant Bed," though commingled with these are bears (*Ursus spelæus*, an extinct species), a glutton, an extinct walrus, an extinct horse, the living narwhal and dolphin, a beaver, three stags, and other species, in addition to one bird and several fishes. Of the elephants, three species have been described, and so numerous are their bones that it is not uncommon for the fishermen off the Cromer coast to bring up specimens in their nets. Altogether, the Forest Bed flora, as well as some of its mammals, exhibits the gradual approach of that frigidity which will be described presently, and above it are glacial clays which contain the Arctic willow, and other species no longer found except in the Alpine and far Northern regions. It may be added that Mr. Carruthers, who examined the Forest Bed plants, could discover no difference between them and the same species now living a few yards distant from them, though the interval between the one and the other has been estimated to be at least two hundred thousand years.

The Pliocene Flora and Fauna. — The most salient feature about the Pliocene flora is not so much the differences which it presents in comparison with that which preceded it, as the evidence which it affords of the gradual lowering of the temperature of the North from the tropical heat of the Eocene and earlier Miocene. Many of the species are the same as in the latter Formation, or, at all events, very closely akin to them. But the palms have vanished. Yet what plants remained were abundant both in species and

* Jamieson, *Quarterly Journal of the Geological Society*, Vol. XVI., p. 371.

in genera, and of such wide range in Europe that from Italy to France much the same vegetation prevailed, though many of the forms are now confined to the Southern and Eastern parts of the world. But towards the close of the Period—as the Forest Beds at Cromer abundantly show—the vegetation did not differ very widely from what is at present characteristic of our islands, none of the vines, bamboos, liquidambars, tulip trees, magnolias, and other semi-tropical trees of the South reaching so far North as what were not then Southern ones which did not migrate out of the chilly air remained to associate with an ever-increasing invasion of Northern forms driven before the advancing ice-sheet, or extended their range as the cooler temperature suited them.

In the preceding Ages we have also seen the animals gradually approximating in appearance to those with which we are at present familiar. Hence Marsh and others have attempted to trace the "ancestry" of modern from ancient species by the intermediate forms

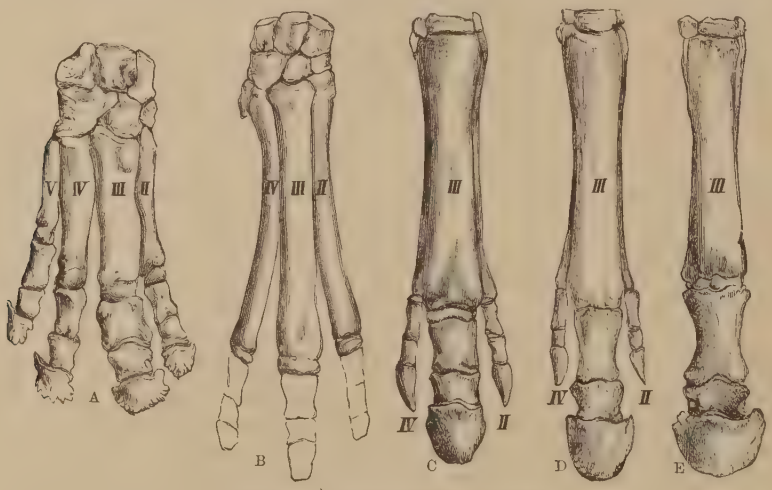


Fig. 155.—VARIOUS FORMS OF HOOFS.

A, Tapir; B, Palæotherium; C, Anchitherium; D, Hipparion; E, The modern horse. [The Roman numbers refer to the number of digits.]

the British Islands, this country being still a part of the Continent. The fauna was distinguished by the number of herbivorous animals—elephants, deer, rhinoceri, and hippopotami—besides bears and hyænas, and an ape (*Mesopithecus*), numbers of which seem to have lived in regions eight hundred miles farther north than their descendants are now found in Europe, the little Barbary ape of the Rock of Gibraltar being the only species of monkey at present inhabiting Europe, and even it, there is reason for believing, was in earlier days brought by man from the opposite shore of Africa. But as we reach the topmost beds of the Pliocene the Northern species become more numerous, though the seen in the Tertiary beds. Thus the genealogy of the horse in Europe and America is supposed to be indicated by the animals of which the hoofs are shown in Figs. 155 and 156.

In Europe the line seems to run from *Paloplatherium*, a tapir-like animal of the Lower Eocene, by way of *Pachynolyphus*, a near ally, to *Anchitherium* (of the Middle Miocene), so far as concerns its teeth, and to *Hipparion* by reason of its limbs. *Hipparion* is, indeed, simply a horse with two small additional toes, one on each side of the hoof, such as are sometimes seen in monstrosities of the existing species. From *Hipparion* to *Equus stenonis* of the Pliocene is a short

Map Showing the

DISTRIBUTION OF VEGETATION

after A. Engler

London: Cassell & Company Limited.

Edw.d Weller

Forms of Vegetation

- Tropical Woods
- Savannahs, Llanos & Steppes of the Tropics
- Pine Woods
- Broad-leaved Woods
- Prairies, Pampas, Plains, etc, of more temperate Zones
- Arctic & Alpine Vegetation
- Deserts

step, and the latter is, to all intents and purposes, the first true horse of Europe.

In America the horse of the Pliocene world seems to have had a different ancestry (Fig. 156). *Eohippus* of the Lower Eocene had four toes, with the rudiment of another on each fore-foot, and three toes on each hind-foot. *Orohippus* (Hyracotherium of Owen) of the Middle Eocene was larger than the preceding genus (which was no bigger than a fox); it had four toes in front and three behind. *Mesohippus* of the Lower Miocene was about as large as a sheep; it had three well-developed toes, and a rudimentary one on each fore-foot, with three

In like manner, Von Ettingshausen has endeavoured to trace the genus *Pinus* back to *P. palæo-strobus* of the Eocene (Fig. 154) and the ordinary chestnut (*Castanea vesca*) through the Tertiary *C. atava, C. ungeri*, and *C. kubinyi* (Fig. 153).

How far these efforts have been successful it is not necessary to inquire. At a later period in our studies we shall have occasion to discuss the questions which they involve; meanwhile it is clear that any attempts of the kind must be always surrounded with doubt and difficulty, and, at best, be merely tentative.

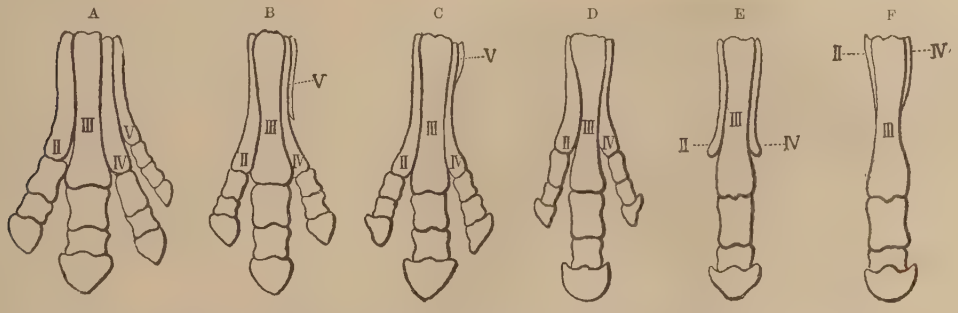


Fig. 156.—FOREFEET ILLUSTRATING THE GEOLOGICAL GENEALOGY OF THE AMERICAN HORSE.

A, Orohippus; B, Mesohippus; C, Miohippus; D, Protohippus; E, Pliohippus; F, Equus. [The Roman numerals refer to the number of the digits.]

toes behind. *Miohippus* of the Upper Miocene has the splint-bone of the outer digit nearly rudimentary, but the middle one is now of considerable stoutness, somewhat after the manner of *Anchitherium*, to which it is closely allied.* *Protohippus* of the Lower Pliocene is a three-toed horse, while *Pliohippus* of the Upper Pliocene has entirely lost the lateral digits. Finally, in the Upper Pliocene and later Formations we find the genus *Equus*, in which the lateral digits or splint-bones no longer play any part in the animal's economy.† It may be added that there is a similar gradation as regards the teeth of the different species mentioned.

* Prof. Scott (*Science*, Vol. VII., Jan. 1, 1886, p. 13) will even make the two genera identical.

† Marsh, *American Journal of Science*, Vol. XVII. (1879), p. 497.

Physical and Economic Features of the Pliocene Period.—The change in the world's features which began during Miocene times—indeed, during the earlier Eocene—seems to have continued all through the Pliocene Period. The sea gradually more and more collected into great oceans, until regions, which in early days were water, now began to appear as dry land. Hence, the occurrence of Pliocene deposits along the edges of the present sea coasts. During this Period, most likely, Europe was severed from America by the submergence of that great volcano-dotted ridge, clothed, as Etna is nowadays, with the oak and the vine and the chestnut (p. 208), which is believed to have extended between Greenland, Spitzbergen, and France, and of which we may regard the Hebrides, the Highlands of Scotland and Wales, the

Orkneys and Shetlands possibly, the Faroes, Iceland, with its volcanoes, Jan Mayen, with a crater which still occasionally vomits forth fire amid the Arctic wastes, and Bear Island, as the lost links.

But England and Scotland were still united to the Continent: and there was a stable union between them and Ireland, in the shape of land where now salt water rolls, though the waters of the North Sea had severed Britain from Norway. In Asia the inland ocean had retired, leaving a chain of great lakes and seas, which stretched from the Black Sea eastward, as the last remnants of that Eocene ocean which had previously connected the Persian Gulf with the Polar Basin, and the Mediterranean with the Indian Ocean. Most of the Pliocene seems to have been laid down in placid waters. Yet the volcanic disturbances from which the basalts of Antrim, Mull, Skye, and the Faroes, date, were continued in the volcanic vents of Auvergne, Vivarais, and Velay in France, of the Eifel and other regions in Germany and Hungary, and, above all, of Etna, of Vesuvius, and the other Mediterranean volcanoes which began their active career during the Pliocene Period. At the close of this Age also the land on each side of the Apennines seems to have risen, this rise throughout the Pliocene area being, of course, the cause of the retreat of the Pliocene sea already mentioned. The Mediterranean, however, was still a larger basin than we know it, and stretched up the valley of the Po right into the heart of the Alps, while much of Sicily, the Peninsula, France, Belgium, and East Anglia, must have been under water. In this Age the geography of Britain was modified in only two important particulars from that of the Miocene Age—the letting in of the Arctic waters into the North Sea, and their free communication with the Atlantic by the submergence of the area between the Shetlands and Iceland. The portion covered by Pliocene beds in East Anglia is so small that we are justified in concluding that Britain, with these exceptions, was in Pliocene times very much what it was in the former Age — neither much smaller nor much bigger. At that Period, as in the Miocene Age, plants and animals could migrate over the dry land, then uniting France, Spain, and Britain together, without being confronted by a physical barrier.* A geographical continuity of this kind must have existed, otherwise it is difficult to account for the presence of Spanish plants, such as *Arabis ciliata*, the fringed rock cress of the west of Ireland, and *Pinguicula lusitanica*, the pale butterwort, which in the British Islands, is found only in Ireland, the south and south-west of England, and the west of Scotland.†

Fig. 157.—THE MAMMOTH (*Elephas primigenius*), AN EXTINCT NORTHERN ELEPHANT COVERED WITH WOOL (RESTORED).

The vegetation and general fauna (Fig. 159) of the earlier Pliocene beds indicate a warm climate, but in the later ones the existence of Northern forms speaks of cooler times, few of the shell-fish being those of Southern seas. Yet among these Arctic or temperate forms

* Dawkins: "Early Man in Britain," p. 74.

† Edward Forbes, *Memoirs of the Geological Survey*, Vol I., p. 348.

we find elephants, rhinoceri, and hippopotami, the presence of which is accountable only on two hypotheses: either they migrated during the winter, or, more likely, were covered with wool like the rhinoceros and mammoth (*E. primigenius*), which latter is found in the Forest beds at Cromer (p. 223), and survived the Glacial Period. Its bones are plentiful in Quaternary deposits in France, Germany, Britain, Russia, Asia (in Siberia its tusks are still gathered for the ivory-cutter), and North America, where the Indians have curious traditions considered to relate to this animal. In these countries it is often associated with the reindeer, musk-ox, and lemming, all essentially Arctic animals; and that it lived into the Human Period is proved—the traditions mentioned aside—not only by the implements of human manufacture found with it, but by a recognisable portrait of it having been discovered carved by a pre-historic hunter on a piece of its own ivory (Figs. 157, 158 D, and p. 34).*

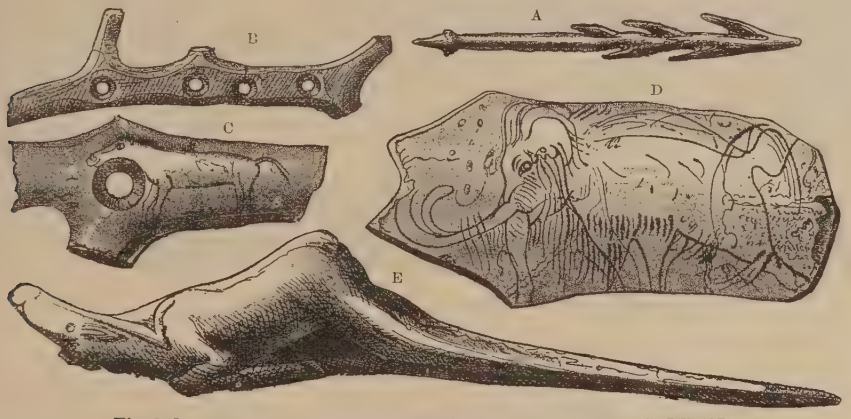


Fig. 158.—WEAPONS AND OTHER RELICS FROM THE REINDEER PERIOD.

A, Harpoon with subsidiary points like the Eskimo spears; B, Supposed "sceptre" or "bâton of command" (more likely an arrow-straightener), from a cave in the south of France; C, Fragment of a similar implement with a figure of the horse scratched on it, from Kesslerloch, near Tayngen; D, Ivory plate with an engraved sketch of the mammoth, from the cave shelter of La Madelaine in the Dordogne; E, Piece of a reindeer horn (a dagger), with the handle rudely carved into the likeness of a reindeer's head, from Langerie-Basse.

* In *Scribner's Magazine* (April, 1887), and in "The Mammoth" (1887), Professor Scott and Mr. Howorth have gathered together most of the information regarding this remarkable animal; and in "The Peoples of the World," Vol. I., p. 135, I have noted some of the Western Indian legends which seem to refer to it.

It is, however, certain that even before the advent of the Glacial Period, floating ice, fragments broken from the floes of the nearing North, or icebergs detached from the seaward edge of the advancing sheet, or of local glaciers forming in the Continental valleys, had appeared in the Pliocene seas. For instance, in the basement bed of the Coralline Crag there are found fragments of Oolite which must have come from the centre of England, and a large block of red porphyry, the home of which must be sought for in a still more distant country. Again, the basement bed of the Red Crag contains quartzite pebbles, fragments of Lower Greensand schist, and red granite, all angular and unworn, and therefore, in all probability, conveyed hither from a distance, and left on the spot where they now lie by the ice-float on which they had been borne.†

As a rule, the Pliocene soils are poor, yielding little from beneath as compensation for the poverty above. Coprolites are dug out of some of the beds, particularly from the Norwich Crag, while the salt and gypsum beds of the Aralo-Caspian region date from the Period now under consideration.

† Prestwich: "Geology," Vol. II., pp. 420, 421.

Fig. 159.—IDEAL LANDSCAPE OF THE PLIOCENE PERIOD.

CHAPTER XIII.

THE CAINOZOIC DEPOSITS: THE PLEISTOCENE SYSTEM.

The Pleistocene Period—Its Chief Characteristic a Vast Glacier Sheet over the Northern Hemisphere—Regions Overspread by It—Nature of It—Successive Ice Periods—Proofs of a Glacial Period—The Various Glacial Remains—Moraines—Scratched Rocks—Boulder Clays, Arctic Shells, etc.—The Parallel Roads of Glen Roy—Cause of the Glacial Period—Numerous Theories on the Subject—That of Croll, and its Modification by Wallace—Objections to this Theory—Views of Penck and others—Date and Duration of the Glacial Period—Results of the Glacial Period—The Fauna and Flora of the Age—Condition of what are now the British Isles at that Epoch—Consequences of the Variations or Alterations of Level in the Distribution of the Animals of the Continent—etc.

THOROUGHGOING alterations in the physical condition of the earth took place towards the close of the Tertiary Period. The warmer and more moderate climate of "Neogene" times (p. 199) was followed by a colder, snowy, and rainy one, favourable to the formation of enormous masses of ice. This period of decreased temperature is known as the Glacial Period, or the Great Ice Age, ample memorials of which have been detected in the higher latitudes of both hemispheres in the shape of erratic blocks, ice-grooved rocks, Arctic shells, etc. (Figs. 28, 161, 162). Mountains and entire countries which are to day free from glaciers were at that time covered with eternal snow. (Fig. 160, and Plate in Vol. I.) The flora of the antecedent period perished to a large extent; and animals which are now confined to the extreme north dwelt then in the heart of Europe.

The present state of things began after the close of the Glacial Period, by slow steps and

under the most varied oscillations of climate. The first appearance of Man in Europe, perhaps on the earth, occurs likewise during, or, at least, immediately before, this latest great geological period of the world's history.

The Glacial Period.

The whole northern hemisphere was buried under ice, which radiated partly from the Scandinavian mountains, partly from the mountain ridges in Ireland, Scotland, and Wales, and extended to 51° lat., to the slopes of the Carpathian hills, and of the Mid-German mountains. The glaciers of the Alps were far larger than they are to-day. All the principal valleys were filled with mighty rivers of ice, which overflowed the Bavarian and Swabian tablelands and the whole of Lower Switzerland. Even mountains which are now free from ice were then partially glaciated—the Cantabrian mountains, the Sierra Morena and Nevada, the Pyrenees, the mid-range of France, the Cevennes; and in Germany the Vosges and the Black Forest. The Carpathians, too, and the Transylvanian hills, were partially glaciated. Corresponding to the great North European glaciation was one of the lowlands of North America which probably proceeded from Greenland. This country is even to-day in its interior a perfectly glaciated region (Vol. I., p. 374), and offers a living picture of the Ice-time. The glacial phenomena were still more extensively developed in North America, (where the continental ice-sheets extended to 39° N. lat.), than in Northern Europe. The whole territory around the lakes which encircle Hudson's Bay was glaciated; and during the greatest development of the Glacial Period the ice-sheet extended into the Mississippi Valley.

Fig. 160.—EUROPE AT THE GLACIAL PERIOD.

(*Darkly striated*): The sources of the great Pleistocene ice-streams; (*Lightly striated*): Areas with traces of former glaciation.
---- Limit of the occurrence of erratic blocks.

Yet in the midst of this great mantle of drift—moraines and other *débris* carried forward or deposited by the ice-sheet—that overspreads the Upper Mississippi Basin, there lies a drift-barren tract of about ten thousand square miles—the driftless area of Wisconsin and adjoining States. This island in a glaciated area shows that the great drift-bordered ice-stream, as it moved south-westward from the Canadian uplands, was divided and diverted by a height of land, around which the separated currents swept and mingled their borders beyond. In the language of Chamberlin and Salisbury, diverted by Highlands, led away by valleys, consumed by wasteage when weak, self-perpetuated where strong, the fingers of the *mer de glace* closed round this ancient Jardin of the Upper Mississippi Valley, but failed to close upon it.*

North Asia seems to have been far less glaciated than either North America or Northern Europe. Traces of enormous glaciation have, however, been discovered in the higher latitudes of the southern hemisphere—in Patagonia and in the South Island of New Zealand; whilst we must regard the Antarctic regions as still buried under great masses of ice.

Dr. Albert Penck has calculated that probably a surface of 7,840,000 square miles was covered with ice in the northern hemisphere.† Of these, 6,080,000 square miles were solid ground, and 1,760,000 shallow water. He estimates the glaciation around the South Pole at 4,000,000 square miles. The height of the ice covering is reckoned as follows:—The North European ice-sheet over the Baltic at over 3,300 feet, the North American of Dana at more than double that depth. The Antarctic ice accumulation is even now calculated by Dr. Croll to be upwards of 10,000 feet thick, judging from the size of the southern icebergs. The plate in Vol. I. shows the principal past and present glacial areas of the world.‡

This vast glaciation was not due, as has sometimes been attempted to be proved by theorists only vaguely acquainted with the nature of Arctic ice, simply to local glaciers, or to ice-floes, or to icebergs. All three were no doubt present. On the mountains at the southern extremity of the ice-sheet there were, we may take it, then as now snows gradually solidifying into glaciers. The chilled seas must have been choked with ice-fields, while from the free border of the great glacier cap when it reached the sea, icebergs would be discharged. Of this, indeed, we have ample proofs in the glaciated bottoms and sides of the Scottish lochs at that time identical with the ice fjords of Greenland (Vol. I., p. 343), and in the Arctic shells which are found in the mud of the sub-glacier stream, which in those days, as in ours—in the far north—burrowed in this material which was constantly discharging from under the seaward edge of the ice-sheet. But everything points to the main features of the Pleistocene Period being a succession of great ice-sheets like that which now covers Greenland, the erratic blocks, the "foundlings" (Vol. I., p. 370), perched in places where the ice-sheet could not well have deposited them, being exceptional instances of the action of icebergs, ice-sheets, or glaciers which in their retreat left their lateral moraine in such positions. As Louis Agassiz puts it, "the whole northern hemisphere became enveloped in a shroud of ice and snow to an enormous depth (which, as in the case of Britain, attained to something like 4,000 feet). The surface of Europe—adorned before by a tropical vegetation, and inhabited by troops of large elephants, enormous hippopotami, and gigantic carnivora—was suddenly buried under a vast mantle of ice, covering alike plains, lakes, seas, and plateaux. Upon the life and movement of a powerful creation fell the silence of death. Springs paused; rivers ceased to flow; the

* "The Driftless Area of the Upper Mississippi" (*Report of the United States Geological Survey*, 1884–5, pp. 205–322).

† The entire glacier region of the northern hemisphere contains at the present day only 640,000 square miles.

‡ Penck: "Vergletscherung der Deutschen Alpen" (1882); Partsch: "Die Gletscher des Vorzeit in den Karpathen" (1882); etc.

rays of the sun rising upon this frozen shore (if, indeed, it was reached by them) were only met by the breath of winter from the north and the thunders of the crevasses as they opened across the surface of this icy sea."

Successive Ice Periods.—Whether the development of ice occurred at one and the same time on both hemispheres, or whether the glacial periods alternated in the two hemispheres, is a problem still unsolved, and is so much the more difficult to solve because

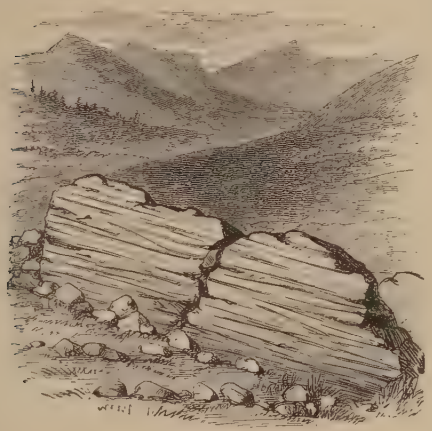


Fig. 161.—ROCKS GROOVED BY ICE.

the geological examination of the old glaciated area, at all events in Great Britain, Germany, Switzerland, Upper Italy, and North America, has led to the unanimous conclusion that the former glaciated surfaces have been subjected to considerable oscillations. Several distinct glacial periods are distinguished in these countries. They were divided from each other by interglacial periods, during which the ice retreated, and a free development of running water took place.

James Geikie* has, indeed, found indications of eight climatic changes since the time when the Polar willow and the dwarf birch grew on the clay over the Forest beds of Norfolk (p. 223). There was (1), a mild preglacial period; (2), the first glacial period; (3), the first interglacial mild period; (4), the second glacial period; (5), the second interglacial mild period; (6), the third glacial period; (7), the third and last interglacial mild period; (8), the last glacial period.

Making allowance for local conditions, and for the varying views due to different interpretations of the same inscriptions, in the shape of glacial remains, this succession was probably very similar all over the northern hemisphere. In North America, for example, Chamberlin recognises in a broad way (1), an earlier glacial epoch in which two successive ice-sheets were separated by an interglacial period sufficiently marked to permit the growth of vegetation over the surface; (2), a prolonged interglacial epoch, during which the land was elevated to the height of 800 to 1,000 feet, and again forest-clad; (3), a later glacial epoch, during which the great terminal moraine marking the southern margin of ice-sheet was formed, while subordinate moraines and plant deposits testify to repeated recessions and advances of the ice; (4), the "Champlain Epoch," during which marine and lacustrine deposits were formed; (5), the "terrace epoch," where the streams from the melting glaciers carved the flood-plains of the Champlain epoch into terraces. To this general dissolution the phenomena known to the Scottish geologists as "Crag and Tail" may be assigned (Vol. I., p. 371). All of these oscillations of climate occurred during a definite period of the world's history, which we know as the *Pleistocene*, or, in more familiar language, the *Glacial Epoch*, or the Great Ice Age.

Proofs of the Glacial Period.—These are so abundant over the northern hemisphere†

* The literature of the Glacial Period is very extensive. It is less satisfactory to add that perhaps no mass of writing is less distinguished by careful observation, ample knowledge, and an acquaintance with what the writers have undertaken to discuss. There are, however, exceptions, and, so far as the English language is concerned, they will be found in abundance. And most notable among these exceptions are James Geikie's "Great Ice Age" (1876), James Croll's "Climate and Time" (1875), and Archibald Geikie's "Phenomena of the Glacial Drift," which forms Part II. of Vol. I. of the Glasgow Geological Society's *Transactions*.

† Agassiz considered that he had found them in the Valley of the Amazon, and there have been hints of their existence in the lake region of tropical Africa. Professor

that there is no mistaking their character, if once the observer has learned to recognise the ground over which modern glaciers have passed, or the remains they leave behind. Without going into the character of these or attempting to arrange them chronologically, since the arrangement is in every region different, and possesses even in different parts of the same district some local variations, they consist of scratched, striated, or ice-worn rocks (Fig. 161), *roches moutonnées*

Fig. 162.—SHEEP ROCKS (ROCHES MOUTONNÉES).

(Fig. 162, and Vol. I., p. 371), like what are found in the Alpine valleys when the glaciers have retreated, and travelled blocks (Vol. I., Fig. 197), also often striated as if they had been borne along on the under surface of the ice-sheet, playing, as they moved southward, the part of a file to the country over which they were dragged. Some of these boulders must have travelled a long way, since rocks not found *in situ* nearer than Scandinavia are seen among the glacial drift in Norfolk. Another characteristic glacial remain is the boulder clay or "till," stiff unstratified clays or loams, containing pieces of travelled stone frequently polished, grooved, and striated. Sometimes the stones in this clay seem as if crushed or deformed by an immense superincumbent weight. Most frequently they seem derived from the rocks underlying the clay, but not very rarely they have come a long distance, embedded in the under surface of the ice-sheet, which has worn by its constant grinding over the surface this curious boulder clay. In other words, it seems to be the bottom moraine—the *moraine profonde*, as the French-speaking Swiss call it—of the ice-sheet, or in some cases of gigantic glaciers which have either disappeared or have, as in the case of those of Central and Southern Europe, shrunk to very moderate dimensions. This till often covers hundreds of square miles in a continuous sheet, and attains in low-lying tracts a thickness of sometimes 100 feet, while under it the rock surface—as at Möen's Klint in Sjeland (Denmark), and at Cromer, in Norfolk—is contorted, or smashed.

The "brick clays" and other stratified drift, full of Arctic shells, are another set of glacial remains. In some cases these clays may be re-assorted boulder clay, but most frequently they are simply the accumulation of mud which has been deposited in a fjord by the stream always pouring out under a glacier or ice-sheet (Vol. I., p. 371). Some of the shells in these clays are figured on p. 37. The boulder clay is—except under circumstances which may be left out of the reckoning—entirely unfossiliferous, though one can readily understand that, if the ice-sheet had protruded itself into the sea—as on a small scale the "ice-blink" in Greenland* does—the clay might accidentally contain some broken shells, etc. The huge pot-holes, or giants' kettles (Vol. I., p. 311), are other remnants of the Glacial Period. So are the "Kames," moraines, and other remains so plentifully scattered over the North. The first-named are generally *débris* well developed, more especially at the mouths of valleys, while ridges not widely different (åsar) often run continuously for over a hundred miles in Southern Sweden. Finally, not to enumerate

Drummond ("Tropical Africa," p. 198) is, however, convinced that there are no traces of glacial phenomena in that quarter. In South Africa, glacial remains have been noticed; but though the glaciers of New Zealand and the Himalayas had once a greater extension than at present, it does not appear that in these regions there was anything corresponding to the great ice sheet of the North.

* "Countries of the World," Vol. I., p. 56.

other less evident or more disputable remains, we find in interglacial beds in the till, remains of the mammoth, the woolly rhinoceros, the reindeer, the great Irish elk (Vol. I., Fig. 27), the musk sheep or ox (an essentially Arctic mammal), the extinct urus (*Bos primigenius*), Arctic shells, Northern plants, etc.

Lastly, when the ice-sheet was melting away under an amelioration of the climate, the plants and animals of the north which had been driven south returned in its train, and vast beds of shingle and gravel were deposited in our valleys and along river-courses; so that the margins of these old ice-floods can still at this day be distinctly traced. As the ice-sheet shrank the lowlands became bare, but the ice still remained in the shape of local mountain glaciers, some of which, as in Norway and the Alps, have not disappeared to this day. But even in countries like Scotland, from which they had for the most part vanished, the lingering ice-sheet in lateral valleys seems to have formed dams by which the water was prevented from flowing away. The height at which it stood is shown by the "Parallel Roads," the popular name of which sufficiently describes their character. They are partly formed by erosion of the lake-shore and partly by the *débris* which fell from the slopes above (Fig. 163).*

Fig. 163.—PARALLEL ROADS OF GLEN ROY, SCOTLAND.

The numerous "raised beaches" along our coasts are the memorials of the last rise of the land, just as we know from the evidence of marine shells and other data that Wales during the Glacial Period sank upwards of 1,400 feet, and Southern Scandinavia at least

* These "roads" have given rise almost to a literature of their own. The reader will find the latest contribution to this in a paper by Professor Bonney in *Science for All*, Vol. V., p. 182.

600 below its present level. As for the gravels, etc., of which we have spoken, the autumn tourist has only to examine Strathmore and the Howe of Mearns in Scotland, when he will find it filled up with this *débris*, while the lochs and gravel mounds which can be traced from Clova to Lunan and Dun are equally patent relics of these far-away floods.*

Cause of the Glacial Period.—It is therefore clear that succeeding the Pliocene Age there was a glacial epoch. But it is by no means so clear what was the cause of this remarkable change of climate. Yet if we do not understand it, the fault does not lie with the theorists, for scarcely any other speculation in geology has attracted a greater number of "explanations." Some years ago, the late Mr. Searle Wood, in discussing the subject, enumerated no fewer than seven theories which have met with more or less acceptance. These are:—(1) The gradual cooling of the earth from a condition of original incandescence; (2) changes in the obliquity of the ecliptic; (3) changes in the position of the earth's axis of rotation; (4) the effect of the precession of the equinoxes along with changes of the eccentricity of the earth's orbit; (5) variations in the amount of heat given off by the sun; (6) differences in the temperature of portions of space passed through by the earth; (7) differences in the distribution of land and water in connection with the flow of oceanic currents. The last is still feebly clung to and no doubt has something in its favour, for, as Sir William Dawson puts it,† the ocean is the great equaliser in temperature. It "does this by its great capacity for heat, and by its cooling and heating power when passing from the solid into the liquid and gaseous states, and the reverse. It also acts by its mobility, its currents serving to convey heat to great distances, or to cool the air by the movement of cold icy waters. The land, on the other hand, cools or warms rapidly, and can transmit its influence to a distance only by the winds, and the influence so transmitted is rather in the nature of a disturbing than of an equalising cause. It follows that any change in the distribution of land and water must affect climate, more especially if it changes the character or course of the ocean currents."‡

This and most of the other theories need not, however, be discussed. In 1846, Louis Agassiz, who first drew attention to the glacial phenomena of Great Britain as proofs of an ice-sheet or cap having passed over the surface (though at that time he was unaware of Greenland being in this condition), broached the doctrine of the "Glacial Epoch," and insisted on the glacial phenomena not being local, but universal—as something by which almost the whole northern hemisphere had been affected. Since then, the very varied hypotheses noticed have been advanced to explain it. But this list by no means exhausts them. The glaciation of the Alps has been accounted for by the supposition of a formerly much more considerable elevation of the range, followed by a later sinking; the glaciation of the North by the supposition of the existence of great masses of land between Norway and Spitzbergen, by an "Arctis," which has now disappeared. The severer climate of Western and Central Europe, it has been thought, was occasioned chiefly by a different distribution of land and water and by other currents of the sea. A sinking of land has been supposed to have taken place in the North—a sinking sufficient for the admittance of the waters of the Polar Sea into the Baltic. In the north-west and west the Gulf Stream which warms the coasts of Europe has been thought to have been non-existent, either in consequence of the breaking through of the Isthmus of Panama, or its deviation by a mythical island, "Atlantis," in the Atlantic Ocean. But as these hypotheses, based only on local phenomena, did not appear to offer sufficient

* Howden, *Trans. Geol. Soc. Edinburgh*, Vol. I., p. 138. In *Science for All*, Vol. I., p. 33, I have given a popular *résumé* of the subject, to which, as well as to the *Arctic Papers of the Royal Geographical Society*, pp. 1–75, the reader may be referred for further information.

† *Presidential Address to the British Association*, 1886.

‡ *See* also Von Woeikoff in *American Journal of Science*, March, 1886.

explanation, a shifting of the axis of the earth, or an alteration of the obliquity of the ecliptic, whereby modern Europe became the Polar region, was supposed to have occurred.

Penck rightly affirms that the whole prehistoric glacial phenomena must be considered as nothing but an exaggerated form of those of to-day. The glacial phenomena of this Epoch were developed on a soil and in districts the physiographical circumstances of which have not changed very much since that time. Glaciers were found in bygone ages where they are found to-day, only to a much larger extent, and where they now cover only a small space they were then proportionally more extensive. It follows, if this be the case, that the explanation of the great development of glacial formations during the close of this Tertiary Period can be found in the increase of those causes which, under all circumstances, lead to glacial formations. These consist in an increased snowfall and a decreased temperature, or, in other words, in a climatic change. And such climatic change must have been itself subjected to general variations, just as were the glacial sheets which, we have seen, were subject to noticeable oscillations. But this brings us back to the question with which we began—What led to these alterations in temperature?

The secular change of climate is explained best, according to the theory of Dr. James Croll,* by the secular variation of the eccentricity of the earth's orbit. Of these terms of high eccentricity he has calculated that there have been four or five in the last 3,000,000 years. At one of these principal periods, during which the Glacial Age occurred, the earth's distance from the sun would have been 8,736,420 miles farther than at present during our Northern winter. Such conditions combined would have made the direct heat of the sun during the winter half of the year one-fifth less, and during the summer half, one-fifth greater than now, thus causing the accumulation of ice. Croll calculates that the difference between the length of summer and winter was thirty-six days in those periods in which the eccentricity of the orbit of the earth was very considerable. Therefore, one hemisphere passed through a glacial epoch the winter of which fell in the aphelion, and thus had a longer winter and a shorter summer than usual, while the other enjoyed an exceptionally fine climate.† This theory has been modified by Alfred Russel Wallace. According to him, both hemispheres can pass through glacial periods at the same time. Croll affirms that during the rotation period of the equinoctial point, the same hemisphere passed through a glacial and interglacial period. Wallace maintains that the interglacial period was not able, even at the time of the greatest eccentricity, to dissolve all the ice which had been accumulating during the Glacial Epoch. These accumulations lasted through several of Croll's glacial and interglacial periods, during which time both hemispheres were to the same degree covered with ice. In times of lesser eccentricity these ice formations disappeared, and boreal and southern ice formations alternated. This explains why, in a period of lesser eccentricity, both hemispheres are unequally covered with ice, the southern more so than the northern, whilst in the Glacial Epoch great masses of ice congregated around both poles.

This theory of Croll's—which we have been able to state in only the briefest of terms—has met with various objections. One of these is that owing to the precession of the equinox the conditions of the two hemispheres must be reversed about every 11,000 years. We ought to find—it is claimed—but do not, in the older Formations evidences of these

* Croll: "Climate and Time" (1875); Wallace: "Island Life," pp. 121–202.

† Stone and Croll have calculated by means of the formulæ of Leverrier that the eccentricity of the earth's orbit was about equal a million years ago to what it is now (the northern hemisphere has the sun now six days longer in the zenith than the southern hemisphere has it). But 850,000 years ago the eccentricity was nearly four and a half times as great as now, in consequence of which, in a certain position of the major axis of the earth's orbit, the difference between summer and winter amounted to 36 days (first Glacial Period?), 400,000 years ago it amounted to 8 days, 200,000 years ago to 28 days (second Glacial Period?), 100,000 years ago, still to 23 days, but 50,000 years ago to only 6·3 days.

oscillations of climate which, on his showing, ought to have happened again and again during the long lapse of time. In reality, apart from the fact that the absence of great land surfaces in earlier epochs was not favourable to the accumulation of glacial masses, such signs do occur in the ice-borne erratics to which again and again we have called attention in almost every Formation noticed from the Laurentian upwards.* Indeed, were we in possession of a complete history of these supposed glacial remains, and of the period during which they took to accumulate, or during which the causes which gave rise to them lasted, it might be possible, by piecing these facts together, to arrive at something like an estimate of the lapse of time occupied in the deposition and solidification of the sedimentary rocks. This objection seems to have stood in the way of Dr. Prestwich's acceptance of Dr. Croll's theory—or hypothesis as he prefers to call it† —since out of 130 to 160 such periods of cold which ought to have occurred in the last 100,000,000 years, only ten such can be indicated, and of these the Permian Period is the only one which there are "reasonable grounds" for believing to have been so characterised.

Though this very conservative view is not generally held, it may be admitted that there is a difficulty in the fact that a good deal of the Glacial Period is unaccounted for on Dr. Croll's theory. He refers the Glacial Epoch proper to the eccentricity which began 240,000 and ended 80,000 years ago. Yet the greater and larger eccentricity of 980,000 to 720,000 years since, "which should have resulted in a greater colder and more extensive glaciation, has left no corresponding traces of such an event in the preceding Tertiary Periods." Still more recently (1888) Prof. Claypole has raised other objections, founded on some facts regarding the recession of the waterfalls of the United States (Vol. I., p. 307). The Falls of Niagara, he argues, must have taken about 15,000 years to dig out the gorge below them, and had been probably receding at a tolerably uniform rate since the end of the Glacial Period, so that the date which Croll fixes for the close of that Period could scarcely be correct. Again, the Falls of St. Anthony (Vol. I., p. 309) were at the head of a gorge seven miles long, and their rate of recession gives an age of 8,860 years to the gorge, which is entirely post-glacial. This, therefore, would give the date of the retreat of the ice from the St. Lawrence and Mississippi Valleys at from 10,000 to 15,000 years ago, so that the cold could not well have been due to increased eccentricity. Even admitting that Mr. Claypole's calculations are correct—and there are wide differences of opinion on this point—the weak part of his argument is the assumption that the Falls in question—and particularly those of Niagara—began at the end of the Ice Age, a statement in contradiction to which not a little could be adduced.

Finally, Dr. Croll's views have been opposed by astronomers on the ground that the climate could not have been affected to the extent required for the Glacial Periods by changes in the eccentricity of the earth's orbit, while physicists are not at one with him in admitting the adequacy of the physical causes to which he assigns such remarkable results. Nevertheless, it is undeniable that in spite of all the many faults found with it, no other theory has even remotely the same claims on the esteem of geologists as the one which has been formulated by this distinguished physiographer.

Date and Duration of the Glacial Period.—As might have been expected, this is a question on which nothing like unanimity exists, since it follows that if the soundness of the premisses is doubted the worth of the deductions cannot be much. Dr. Croll assigns 160,000 years for the duration of the last Glacial Period, and 80,000 years as the time which has elapsed since the ice cleared away. But not a few geologists, Sir Charles Lyell among the number, have not hesitated to consider the latter period as far too short for the changes in the earth's surface which must

* Ramsay, *Presidential Address to the British Association* (1880), pp. 17–20.

† *Quarterly Journal of the Geological Society*, Vol. XLIII., p. 393.

Fig. 164.—TUMULI OR MOUND GRAVES (HÜGELGRÄBER) AT STANISLAU IN EAST GALICIA.

(From a Sketch by Prof. Oscar Lenz.)

have been accomplished since the end of the Ice Age. In short, the alterations in the level of land in opposite directions, the excavations of valleys, and the variations in the range and distribution of animals and plants, all of which take place at a very slow rate, could not be accounted for by less than three times that interval.* On the other hand, Dr. Prestwich inclines to the opposite extreme. He admits that it is difficult to conceive of valleys in Britain and in the north of France having been excavated to the depth of from 80 to 150 feet in a comparatively short geological term; but he is equally at a loss to understand how Man could have existed 80,000 years (or more, if we allow that he lived before the Glacial Period), and that existing forms of plants and animals should have survived during 240,000 years — or more—without modification or change. On these somewhat insufficient grounds he is not therefore prepared to affirm that the Glacial Epoch lasted longer than from 15,000 to 25,000 years, or that more than from 8,000 to 10,000 years have elapsed since the ice-sheet melted away. This would give from 20,000 to 30,000 years—on a rough approximation—for Man's age, and from 10,000 to 15,000 years if the deposits in which his earliest remains are found be assigned to the post-Glacial Period. This, however, is a question which will be considered in the next chapter.

Results of the Glacial Period.—The leading characteristic of Pleistocene times was the coldness of the climate. But, as we have seen, there were alternations of Arctic periods, with intervals during which the temperature was mild. The fauna and flora must therefore have shared in these variations, the plants and animals migrating and returning according to the warmer or colder conditions which obtained in their area. The shells in the Pleistocene deposits all belong to existing species, most of them being Arctic, but numbers of the mammals are extinct. Some of those of which we find the remains are evidently survivals from Pliocene times. But early in the Period we find that the old tropical and semi-tropical forms began to retreat south. The apes, which in the Upper Pliocene were found as far north as Italy, disappeared in Pleistocene times from Europe, unless we regard the Barbary apes (*Macacus inuus*) in Gibraltar as native and not introduced. As the ice advanced southward it drove before it the Arctic animals and plants, though, as recent observations in Greenland prove, it did not overwhelm the whole of that country, some of them might have remained in the north all through the Ice Age. Then when the ice-sheet disappeared they followed it north. Hence there was a mingling of species, and an immensely greater number of mammals in Europe and the northern hemisphere generally than now exists in the same region. Among the species of temperate habit which at that epoch inhabited Great Britain were many now found only in the temperate zones of Asia, America, and Continental Europe—such as the musk shrew of Southern Russia, the pouched marmot, and a tailless hare (*Lagomys spelæus*). The bison, now only preserved from extinction in the forests of Lithuania, roamed over Europe as far to the north-west as Yorkshire; while the American species (the "buffalo"), now all but extinct in the New World, extended to the Asiatic shore of Behring Strait, and probably beyond. Mingled with its remains in Europe are those of the horse, not now known in a wild state,† the grisly bear, the wild boar, the urus, the lynx, the brown bear, the saïga antelope, etc. Among the Arctic species are the Norwegian lemming, the Arctic lemming, the musk ox, the reindeer, the Arctic fox, and the glutton; while the snowy vole, the Alpine marmot, the chamois, and the ibex, are mammals now restricted to cold mountainous regions, and not found anywhere near Britain. The species which seem to have migrated

* Lyell: "Principles" (10th Ed.), Chap. xiii.; Evans: "Ancient Stone Implements," Chap. xxv.; Lubbock: "Prehistoric Times," p. 403; etc.

† The so-called wild horses of South America and elsewhere are simply escapes from tame herds. The *Equus prejevalski*, recently discovered in the deserts between the Altai and Thian-Shan Mountains in Central Asia, is a different species from our *E. caballus*, and is not known as a fossil.

north either during hot summer or during the temperate intervals were the porcupine of Southern Europe and Northern Africa, the

Fig. 165.—MOLAR TEETH OF MASTODON.

lion, the leopard, the African lynx, the Caffre cat, the spotted hyæna, the striped hyæna, and the African elephant; while Cuvier's beaver,

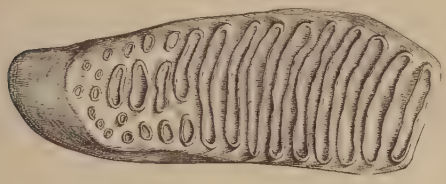


Fig. 166.—MOLAR TOOTH OF MAMMOTH.

the straight-tusked elephant (*Elephas antiquus*, Fig. 168), the mammoth (Fig. 166), the pigmy or "donkey" elephant of Malta (*E. melitensis*), a species not more than four and a half feet high (Fig. 167), Falconer's elephant(*E. falconeri*), which was smaller still, since its height did not average three feet, the woolly rhinoceros, the small-nosed rhinoceros, the great Irish elk, with antlers not unfrequently extending ten feet between tip and tip, the pigmy hippopotamus, the cave bear (*Ursus spelæus*)—a most characteristic sketch of which has been found scratched on a fragment of schist from the cave of Bas-Massat in Ariége—and a cave lion, the only British lion to which any zoology less mythical than that of the heralds bears witness (Fig. 20, p. 29). Many of these animals survived the Glacial Period. But others disappeared with it, or were entirely exterminated when the mild climate of the early Pleistocene was succeeded by the Arctic one of the Ice Period. "We live," Mr. Wallace tells us, when discussing the comparative meagreness of our modern fauna compared with that of Tertiary times, "in a zoologically impoverished world from which all the largest, and fiercest, and strongest forms have totally disappeared."

Fig. 167.—MOLAR TOOTH OF PIGMY ELEPHANT (*Elephas melitensis*).

Fig. 168.—MOLAR TOOTH OF ELEPHAS ANTIQUUS.

In South America the evidences of a great ice-sheet are mainly confined to Tierra del Fuego, in the extreme south; and outside of that area the Pleistocene fauna consists of a

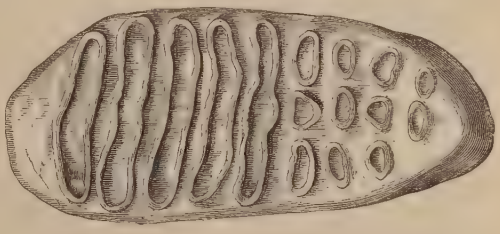


Fig. 169.—MOLAR TOOTH OF ELEPHAS MERIDIONALIS, FROM NORFOLK.

mastodon (Fig. 165), an American elephant, horses of a large size, tapirs, bears, lions, beavers, etc., in addition to extinct species of sloths, such as the well-known *Mylodon*, *Megatherium*, and *Megalonyx*, with armadillos of a gigantic size (*Megalodon*), and other mammalia closely allied to species still existing there (Fig. 171). Though traces of glaciers have been found in South Africa, and in the Atlas valleys, we have not yet there, any more than in New Zealand (p. 232) been able to assign any special fossils to this Age.

This curious assemblage of animals, now living in totally different parts of the world, points not only to great climatic changes, but to the physical geography of the world having been different during the Pleistocene Age. The great continents and the great oceans seem to have been always pretty stable. But districts now separated by the sea were united, owing to the elevation of the land which happened about the close of the Pliocene Period. Britain was still a part of the Continent, and where now the German Ocean, the Irish Sea, and the Channels roll, herds of elk, wild oxen, elephants, rhinoceri, hyænas, lions, mammoths, and other lost tribes of beasts grazed. If the bottom were raised only 600 feet (Fig. 170) this vanished territory would be restored to us, and a rise of 180 feet would unite Britain with France. The margin of the 600-feet line marks the edge of a plateau, probably at that time the Atlantic coast line of North-western Europe. Farther west the lead takes a sudden plunge into 1,000 feet of water (*see* Plate of Depths and Bottom Temperatures of the northern part of the Atlantic): at that point we have evidently reached the utmost limits of Pleistocene Britain. The invasion of African animals proves that the Strait of Gibraltar did not then separate Europe from Barbary, but was a land passage which permitted the elephant to range as far north as Madrid, and the lynx and spotted hyæna to prey in the Iberian peninsula. Sicily must have been united to Africa and Italy when the African elephant lived on that island, and the striped hyæna passed into the south of France; while with Malta and Crete it must have been part of a now submerged continent in the rivers of which the pigmy hippopotamus swam. Finally, the distribution of the living species of Ibex points to the mountains of Crete, Greece, Sardinia, the Cyclades, and Asia Minor having been connected by a land bridge, which would necessitate the Mediterranean having been 2,400 feet above its present level. In other words, it must have been two land-locked basins. By-and-by these land communications were broken down. But this was in the period which, for convenience' sake, we have considered as the Quaternary, and others the Post-glacial and Recent. Then it was that Britain severed connection with its neighbours, and as the valley between England and Ireland was the deepest the Emerald Isle went before France did. This, as our friend Dr. Howden has elsewhere remarked, was "Ireland's first and greatest grievance." But owing to the earlier severance of the western portion of the United Kingdom, when the eastern was still united to the Continent, 40 of the German mammals are found in England and Scotland, but only 22 in Ireland. Of the 22 German reptiles

Fig. 170.—MAP ILLUSTRATING HOW A RISE OF 600 FEET (100 FATHOMS) WOULD UNITE GREAT BRITAIN WITH IRELAND AND THE BRITISH ISLANDS WITH THE CONTINENT.

and amphibia, 13 got to Britain, while only 4 came within the range of St. Patrick's will. Of the British birds and bats Ireland has been done out of 20 of the one and 5 of the other, and of 1,425 flowering plants and ferns she has no more than 970.*

These migrations must have been accomplished during the successive submergences and elevations of which we have spoken (p. 231). This permitted successive troops of mammals to cross from the European continent, and for the caves to get occupied by hyænas, lions, wolves, and bears, where we now find their remains. Above all, it enabled at least two races of men to reach the English shores, dry-shod, and to hunt the horses, reindeer, elks, elephants, and rhinoceros, which grazed on what are now the Dogger Bank and the Bristol Channel.

In crashing over the surface the great ice-sheet must have altered the configuration of much of the country. It changed the river courses in many instances, and by "commingling the detritus of the different geological formations" produced "widespread drift soils of varied composition." As a rule, however, the boulder clay is barren, though in the Lothians and in Norfolk and Suffolk it is extremely fertile, when its component materials happen to be rich in plant-feeding elements. Unless where lightened by the presence of stones, the clay is very tenacious. But in Suffolk and Essex, owing to its chalky character, it was at one time much used as a dressing for other soils.

Fig. 171.—IDEAL AMERICAN LANDSCAPE OF THE LATER PLEISTOCENE PERIOD.

* Dawkins: "Early Man in Britain," pp. 95-123.

CHAPTER XIV.

The Quaternary Period: Prehistoric Man and his Dwelling-places.

Definition of the Period—The Formations at Present in Progress—The Principal "Fossils" in the Quaternary Beds are Man and his Works—His Appearance at an Earlier Date—History of the Evolution of Public Opinion on this Question—Discoveries in the Caves—Man in Europe—History of Civilisation Different in Different Countries—Hence the Ordinary European Classification not Applicable to them—Older Stone Age—Liége Caves—Périgord Caves—English Caves—Muggendorf Caves—The Neanderthal Skull—Swabian Caves—Räuben Caves—Kesslerloch, etc.—The Gibraltar Caves show an Advance—Rising and Sinking of Gibraltar Rock and other Coasts—How these Caves may have got Filled—Discoveries in Open Strata—Abbeville—Schussenried—Wetzikon, etc.—Races Inhabiting Europe in the Stone Period—New Stone Age—Weapons—Dolmens—Tumuli—Menhirs—The Men who Built them—Kökkenmöddings—Lake Dwellings—The Metal Age—Remains of the Age—Tombs in Russia, Poland, Austro-Hungary, and other Countries—Hallstadt Burial-place—Urn Graveyards—Prehistoric Man in America, etc.—Conclusions—The Coming Man.

Under the Quaternary, or Fourth Great Period of the world's history, we class all the deposits which may be regarded as of recent origin, and especially those in which the species of plants and animals embedded are either all still living, or, like the few which have been exterminated by Man, have become extinct within historical periods, though not unfrequently their range is very different from what it was in earlier times. To this category belong the löss (p. 9), no matter how formed, the river alluvia which are forming deltas in which are naturally embedded animals and plants contemporary with them, the ejecta of modern volcanoes, the deposits from springs and geysers, bogs or peat mosses, the stalagmitic and other droppings on the floor of caves, the sand dunes and drifting sands which are so marked a feature in many parts of the world (Vol. I., pp. 8–11, 350, 351), the result of the wear and tear of glaciers, of the rain, or of the wind that "sows the dust of continents to be"—in brief, every kind of accumulation which is at present going on. *We* are living in the Quaternary Period, and it may be that our remains, and our rude tools, if any survive as long as the more durable ones of flint have lasted (which is extremely doubtful), will be objects of geological or archæological interest to the men of some Quinquenary Epoch still in the womb of time.

Indeed, though for convenience' sake we divide this Period from the one preceding it, there is really no hard and fast line between the two. The one shades imperceptibly into the other, just as in most parts of the world the later Tertiary deposits do, the difference being more in degree than in kind. It is, in truth, questionable how far the Glacial Period has actually vanished. We have no longer an ice-sheet crawling over the Scottish plains, and icebergs have ceased to "calve" in the western fjords. But Greenland, Spitzbergen, and other parts of the far north, are still covered with a glacial cap in every respect identical with that which has been described in the preceding chapter. What is more, it is not unlikely a remnant of it; for though encroaching in some places, the Greenland "inland ice" must have at one time covered all the lower coast-lying "outskirting" ice-shaven islands now clear of it. It is also open to regard the glaciers of the Alps, the Pyrenees, and other parts of Europe, including Norway, where, in one place at least (Jökuls Fjord), they discharge icebergs, and those of the Rocky Mountains, the Cascades, the Selkirks, the Sierra Nevadas, and the coast range of Western America, as lingering remnants of that Great Ice Age which is only a piece of geological history in the lower lands at their base.

The deposits of the Quaternary Formation are quite as rich, from an agricultural point of

view, as those of earlier formations. Löss and silt form everywhere soils well fitted for cultivation. Deposits of gravel, sand, and clay, furnish material for building and road-paving purposes. In more distant countries and territories, as in the Urals, in Brazil, in California, in British Columbia, in British India, and in Australia, the Quaternary beds of gravel and sand are rich in gold, platinum, tin, and precious stones, which are obtained by washing the so-called "pay dirt."

Not less important are the palæontological remains of the Quaternary Formation. The Glacial Period did not herald a new flora or fauna. It only interposed itself like a wedge between the one which began in the Pliocene, and was continued, with the occasional disappearance of a species, or the introduction of a new one into the Pleistocene, on to our own times. But after the ice had disappeared it was seen that many forms had vanished—killed off or driven into lower latitudes—or, following the sheet in its retreat, had taken refuge in far northern regions, where their homes are at present. Some, like the mammoth (Figs. 157, 158 D), the Irish Elk (Vol. I., Fig. 27), and the formidable *Elasmotherium*, an unicorn-like animal allied to the rhinoceros, but more fleet and active and of immense size, might have survived it. Indeed, it is affirmed that traditions of their existence still linger in Ireland, America, and Siberia, in some of the leg-ends of dragons, monsters, and the like. But others of which neither tradition nor history has anything to say, like the woolly rhinoceros (*Rhinoceros tichorhinus*), the cave bear (*Ursus spelæus*), distinguished by its high frontal bone and temporal fossæ, the cave hyæna (*Hyæna spelæa*), related to the spotted African hyæna (*H. crocuta*), and the cave wolf (*Canis spelæus*), have entirely vanished. But it does not necessarily follow that Man was not their contemporary; for in the caves in which they took refuge, or into which their bones were swept, their remains are found associated with those of Man. Sketches of their remains (Figs. 158 C, D, E) are also found engraved on pieces of bone, ivory, and stone, by the rude hunters who daily pursued them, which leave no doubt as to their contemporaneity with these now vanished beasts.

Resting-places of Prehistoric Man.

Among the best-known of these caves in Germany are those of Muggendorf and Gailenreuth, the caves of Hohlenfels, Kesslerloch, in the Franconian Jura, the Hohlestein in the Swabian Alb, of Ojcow in Poland,* etc. In Austria the caves of Sloup, the Vypustek cave near Blansko, in Moravia, and the Kreuzberg cave near Laas in Carniola and in Hungary, the Agtelek cave, the Igritz cave, and many others, may be mentioned. These are bear caves, and contain remains mostly of *Ursus spelæus*. The best known English caves are those of Kirkdale, near Kirkby Moorside, in Yorkshire; the cave near Brixham; Kent's Hole, near Torquay; the Dream Cave, near Wirksworth, in Derbyshire; Banwell Cave, in the Mendip Hills; Oreston, near Plymouth; Cefn, near Denbigh; and Paviland, near Swansea. Those of France are in the Dordogne near Vesoul, Montpellier, Narbonne, Meremont, and other places. In Belgium, those in the valleys of the Lesse and Molignée, Engis, Engihoul, Chokier, and others near Liége, have a distinct place in scientific literature. Others exist in the Ural Mountains, in the Rock of Gibraltar, in Sicily, in Malta, in Australia, and in North America and Brazil. But in the Australian caverns there are no human remains, and in Brazil the bones found can only be doubtfully affirmed to be contemporary with those of the extinct animals contained in them.

These caves when not mere fissures, like some of those of Gibraltar, are formed in much the same way (Vol. I., p. 41), and most of them were shelters for wild animals long before Man utilised them either as dwelling-places, or as places for the entombment of his dead. From the floor of the Kirkdale Cave remains of between 200 and 300 hyænas have been disinterred, besides bones of the animals on which they fed, bisons, horses, reindeer, the Irish elk, and occasionally

* Römer: "The Bone Caves of Ojcow, in Poland," translated by J. E. Lee (1884).

elephants and rhinoceros. In the bone-breccia of Auvers, in France, which is of very small extent, not less than 5,000 fragments of the bones of elephants, rhinoceri, hyænas, lions, and other animals dating from before the Glacial Epoch (as most of these caves did) have been found; while, such was the enormous quantity of bones in the Grotta di San Ciro, in Sicily, that in six months as much as twenty tons, mainly those of hippopotami, were exported for the use of the Marseilles lampblack manufacturers. Most of these animals have been already noticed (pp. 238, 239). But what calls for their study in this place is not so much their association with the Quaternary Period as the fact that in the caves in which they are found so many of them are commingled with the bones of Man and of his work. He, indeed, is the most remarkable of all the Quaternary fossils; and though traces of him have been every now and again turning up in previous Formations, from the Pliocene upwards, it has been thought better to reserve some account of his chronology until the subject could be considered in its entirety.

A few decades ago naturalists assumed with unwonted unanimity—basing their judgment principally on the authority of Cuvier—that there were no fossil remains of Man; that is, that no human remains existed contemporary with the extinct mammalia of the cave lion and bear class. Certainly a great deal has been read and heard about human giants whose bones have been excavated in different places; but these giants' bones have always turned out, when more closely examined, to be not human bones, but those of the mammoth and the rhinoceros. The celebrated skeleton, too, from the Miocene calcareous beds of Œningen, on the Lake of Constance (the *Andrias scheuchzeri*), which the Swiss naturalist Scheuchzer considered as a human skeleton of the time of the deluge, has been proved to be nothing but a great salamander, very similar to the giant salamander (*Megalobatrachus maximus*), which lives at the present time in Japan (pp. 29, 213).

This entire want of human remains used to be considered formerly as the most important palæontological distinction between "diluvium" and "alluvium"—the older and the newer aqueous deposits. An entirely different opinion is held to-day. Not only has the belief in the very great age of many of these mammalia become much more unsettled in consequence of more recent investigations, but human remains and man-made implements have been found during late years in different parts of Europe and America in their original resting-places, with the associated remains of mammoths, cave bears, reindeer, etc. The existence of Man during the late Tertiary or early Quaternary Periods has, therefore, become a scientifically settled fact;* and there is now no doubt that the extinct Pleistocene mammalia lived in the company of Man, and were in some cases exterminated by him, probably in the same manner as were, later on, the Irish elk and the aurochs. It follows, if this be the case, that Man experienced at all events, the second glacial period in Central and Northern Europe. But the Quaternary Period in the history of the development of our earth is called justly the Period of Man. For in it we find not only his undisputed remains, but his works also; and though in length of time the epoch is not comparable with any of its predecessors, it is, on account of its human associations, infinitely more important.

Man in Europe: the Stone Period.

The science which occupies itself with the earliest traces of Man's existence is called Pre-history. Its purpose is to inform us, both anthropologically and ethnographically, about the first inhabitants of our continent, of whom neither tradition nor history preserves any record. It speaks to us about the peculiarities of these races, of their settlements and dwelling-places, of their places of offering and burial, and of their weapons, tools, and

* Human remains, or man-made implements to which a greater age can with certainty be assigned—that is, Miocene remains—have been, as yet, nowhere discovered, though attempts have been made to assign some rudely-broken flints to that remote date. Of course—though the evidence is insufficient—the possibility of these existing is still on "the knees of the gods."

other implements, which have been taken at different times from the soil.

In this sense all peoples and all countries have a pre-history. But it is by no means everywhere simultaneous, as the actual limit between history and pre-history is very different with different races. The historical

Fig. 172.—TYPICAL MODERN PROGNATHOUS (PROJECTING) DOLICHOCEPHALIC (LONG) SKULL (MALE MONBUTTU NEGRO).

traditions of the Chinese and old Egyptians go back 4,000 or 5,000 years, and those of the people of classical times to at least 2,000 years before our era. But for Central Europe —Great Britain, the countries of the Danube, and of the Alps and Germany—real historic time begins only at the commencement of the Christian era with the colonisation by the Romans at the time of their imperial power, or with such information as Greek and Roman writers of the first and second century have handed down to us. In the north it begins with the introduction of Christianity, between the fourth and eighth century. Still nearer to our own times comes the prehistory of the American races, who, for us, entered into history only with the discovery of America, and with the conquests of the Spaniards during the fifteenth and sixteenth centuries. The history of the Australians and Polynesians does not begin before the end of the last century, with the discoveries of Cook and other navigators. Finally, that of many African tribes dates no further back than our own times, though in the north of their continent is found one of the most ancient civilisations in the world. The darkness of prehistoric times occurs, therefore, in different countries and with different nations nearer to or further from our own date. In other words, while some of the Eastern peoples were in a condition of high culture, those of Europe were living in caves, and ignorant of any weapons except those of stone. On the other hand, there were not many years ago, to the writer's knowledge, tribes in Eastern Oregon and Idaho who still used obsidian-pointed arrows, though a few miles away was a European people who had for ages been in a state of the most advanced civilisation. We are, however, concerned here only with the pre-history of man in Europe, or with the palæoethnology of Europe.

Fig. 173.—TYPICAL MODERN BRACHYCEPHALIC (SHORT) SKULL (TURK.)

The Prehistoric time is usually divided by the northern antiquaries into three periods: the Stone, Bronze, and Iron Ages.*

* In this brief sketch only the leading facts are given. A fuller account will be found in James Geikie's "Prehistoric Europe" (1881), Lubbock's "Prehistoric Times" (1876), Lyell's "Antiquity of Man" (1880), Evans' "Ancient Stone Implements" (1879), Dawkins' "Early Man in Britain" (1880), Lartet and Christy's "Reliquiæ Aquitanicæ" (1865–1875), and, among other works, the

But it is more in accordance with the facts which have been established in Central Europe to divide it after the proposal of Professor Ecker into two periods: a Pre-metallic and a Metallic time.

The Pre-metallic, or Stone, time is again divided into an earlier, or Palæolithic,* and a later, or Neolithic,† Period. To the Palæolithic Period (still included in the Diluvial epoch of the older geologists) belong, above all, the cave-deposits—that is, the remains of Man in caves—in which he first found his habitation, partly for protection against the inclemency of the weather, partly as a basis whence securely to wage war against wild beasts, and a spot where he might enjoy in peace the spoils of his hunting. Here also he found his last resting-place (Fig. 175). Hundreds of such old cave-dwellings and burial-places, though not, perhaps, all belonging to the same Period, have, we have seen (pp. 243, 244), been discovered in the Calcareous Formations around the Mediterranean, in Egypt, Syria, Greece, Italy, Spain, and France; also in the Oolitic Formations of Switzerland and Germany, in the Calcareous caves of Lower Austria, Moravia, Poland, and Galicia, in Carinthia, Carniola, and Styria, and in Belgium and England.‡

Older Stone or Palæolithic Age.—The characteristics of the cave-deposits of the Palæolithic Period are the occurrence together of human bones or man-made tools, with the remains of the above-mentioned mammalia, which have either become quite extinct or are now completely removed from the locality, the crude workmanship of the stone and bone tools, and the complete absence of metals.

We may now describe briefly some of the most important discoveries made up to the present time. The caves of Engis and Engihoul, near Liége, were explored by Dr. Schmerling as early as the year 1833. He found, amongst other things, two human skulls and flint tools mixed up with the remains of cave bears and cave hyænas, but this discovery did not attract any further attention. The later discoveries of Dupont (1866) in the caves on the banks of the river Lesse, a tributary of the Meuse, in the province of Namur (Trou du Frontal, Trou Rosette, Trou de Nutons, etc., near Furfooz), which we shall presently describe, confirmed the discovery of Schmerling.

In France the caves of Périgord (in the Dordogne), which were examined by Lartet and Christy (1864–1874), are of great importance. Among other localities, caves remarkable as human dwellings and human burial-places dating from the reindeer period have been found in the valley of the Vézère, a tributary of the Dordogne. Le Moustier, La Madelaine, Les Eyzies, Cro-Magnon, and Langerie-Basse, are the names of the best-known caves on the slopes of this valley (Fig. 158 D, E). The soil upon which human beings once dwelt consists here of broken or split bones of the reindeer, bison, horse, chamois, musk-ox, etc., mixed up with crude implements, weapons of bone and unpolished stone, with cinders and charred stones, which indicated the position of the fireplaces. Knives, sharpeners, spear-heads, hammers, and saws, made of flint or hornstone, lie about, in company with needles, arrow-heads, harpoons, etc. But most interesting of all are the carved horns of the reindeer, and the figures of reindeer and horses scratched on these horns. In the

whole subject is discussed from an ethnological point of view in "The Peoples of the World," Vol. V., pp. 110–163. In these pages the geological aspects of the question are alone touched upon.

* Greek, *palaios*, ancient; and *lithos*, stone.

† Greek, *neos*, new; and *lithos*, stone.

‡ Professor Boyd Dawkins ("Cave Hunting," 1876) considers that none of the caves contain remains older than mid-Pliocene. The palæolithic caves are again divided by M. Lartet, in accordance with the species of mammalia they contain, into four groups: caves of the period of the bear, of the woolly mammoth or woolly-haired rhinoceros, of the reindeer, and of the bison. M. Dupont, however, marks only two periods, and divides the Belgian caves into those of the mammoth and of the reindeer period. But all these divisions according to the remains of animals are very uncertain, as it is known that most of these animals were living north of the Alps and Pyrenees at the same time, and are found together in almost every cave of those regions. It is, however, curious that though some of these caves must have existed in Pliocene times, we do not find any of them inhabited by Pliocene animals.

cave of La Madelaine has been discovered a piece of a mammoth tusk, on which the figure of a mammoth has been roughly drawn (Fig. 158, D). The discoveries made by Dr. Falconer in the Brixham Cave, in a hill overlooking Torbay, in Devonshire, where flint tools were found (1858) in undisturbed red clay, together with the remains of the woolly rhinoceros and mammoth, ended for ever all reasonable doubt as to the contemporaneity of the remains of Man and the extinct Pleistocene mammalia, which had been questioned when similar finds were made in 1825 by the Rev. James MacEnery, and in 1833 by Dr. Schmerling, of Liége.

But the earliest examinations of caves were made upon German soil. The well-known caves of Muggendorf, situated in Franconian Switzerland, were scientifically described, first by Esper, in 1774, then in 1804, by Rosenmüller, and in 1810 by Goldfuss. It was Esper, therefore, who, more than a hundred years ago, established scientific proof, based on his discoveries in the cave of Gailenreuth, of the contemporary existence of Man and the Pleistocene animals, though his researches have been confirmed and extended of late years by the labours of Gümbel and Zittel.

Among cave discoveries, one of the most notable was that of the finding of a human skeleton in the year 1856, in the Neander valley, near Düsseldorf. The cranium of this primeval man (*Homo neanderthalensis*, the "Neanderthal man," as he has been called) is of a long elliptical form (dolichocephalic), and exhibits an extraordinary development of the frontal cavities. These cause so great a protuberance of the eyebrow arches, which blend with one another in the centre, that the frontal bone behind exhibits a remarkable depression, making the forehead appear low and narrow. These peculiarities have been considered as characteristic of a low type, uncivilised, prehistoric man whose existence has been assumed.* Virchow, however, has set aside the skull of the Neander valley as a type, and has pointed out in it sundry morbid appearances, such as not unfrequently present themselves in modern crania. Professor Fraas has lately drawn attention to the traces of the Swabian primeval man in the Swabian caves. In the rock grottoes, called Osnet, in the neighbourhood of Nördlingen, in the Ries, a layer of earth, over three feet in thickness, furnished between 3,000 and 4,000 bones and tusks of mammoth, rhinoceros, wild boar, cave lion, cave hyæna, wolf, horse, ass, urus, elk, and reindeer, together with parts of human skeletons and man-made tools, etc.,—such as fragments of flint, potsherds, corn-bruisers, and other things. In the caves at Schelklingen, in the valley of the Ach, near Ulm, were found bones of three extinct bear species (*Ursus spelæus*, *U. priscus*, and *U. tarandi*), and of cave lions and hyænas, also of the lynx, wild cat, otter, marten, fox, squirrel, and musk ox, and of many northern birds, such as the wild swan, the snow-goose, the heron, etc., besides numerous flint knives, tools of bone and horn, and fragments of pots and vessels which allow us a curious glimpse at the life of the "troglodytes" who inhabited those caves (Fig. 174).

The excavations, too, which were made by Zittel and Fraas in the Räuberhöhle, on the Schelmengraben at Etterzhausen near Regensburg, have proved the contemporary existence of Man with the great Pleistocene beasts of prey, and with the mammoth and the reindeer. Some of the latest cave discoveries are those described by Professor Schaaffhausen, which have been made in the Wildscheuer and the Wildhaus on the Lahn, and those made in the Kesslerloch,‡ near Tayngen in the Canton of Schaffhausen on the Lake of Constance (Fig. 158, C).

In Austria there have been well authenticated remains of cave-dwellers of the reindeer period discovered in the caves of the Kamp districts in Lower Austria, and in the Moravian caves near Blansko and Stramberg.

* Traces of the so-called "anthropoid race," which would supply the "missing link" between Man and Ape, have not as yet been discovered, though every now and again weapons affirmed to be of his manufacture are reported to have been found.

* Merk's "Kesslerloch," translated by J. E. Lee (1882).

Among the numerous other European caves those of Gibraltar deserve a brief notice. They are the usual hollows in the limestone rock at various heights to as much as 1,000 feet above the sea level. Besides these there are numerous fissures intersecting the Rock, many of them containing masses of osseous breccia which was described by Cuvier in his "Ossements Fossiles." But though many caves exist along the shores of the Mediterranean, at Nice, Antibes, in Sicily, and other places, it was not until 1863 that they were systematically explored, when by a mere accident the Genista Cave was discovered. Like St. Michael's Cave, it is not a sea-board grotto excavated in the ancient cliffs by the waves, but one of the great vertical fissures by which the rock was rent at remote epochs. It was full of the remains of quadrupeds and birds, of the former of which "some are now wholly extinct, others extinct in Europe, and repelled to distant regions of the African continent; others either now living on the Rock or in the adjoining Spanish Peninsula." Among the former are rhinoceri of four species, and a species of wild swine. An elephant (*E. antiquus*), a molar and jaw of which have been found at Tangier on the opposite shore of the Strait,* is also among the Gibraltar prehistoric fauna. A hyæna (*H. brunnea*), now only living in South Africa, and an ox equalling the aurochs, or European bison, in size, were among the second category; while, besides a leopard, a serval, a tortoise, and the Barbary stag, there were found in vast abundance two forms of ibex, both probably extinct.

Fig. 174.—IDEAL EUROPEAN LANDSCAPE IN THE PLEISTOCENE PERIOD.

Human remains were found very plentifully

* Ramsay and Geikie, *Quarterly Journal of the Geological Society*, 1878, p. 514. The Gibraltar tooth, like the Tangier one, was found in a raised sea-beach.

in the upper chambers accompanied by stone implements of the Neolithic Period, broken querns, or hand-mills (p. 160), and a large quantity of pottery, so that the people who inhabited Gibraltar at a date before the land-bridge between it and Africa was severed were more highly advanced in culture than the races who hunted the now extinct animals in Central and Northern Europe, if indeed (which is by no means certain) they were contemporary with the bones. This, indeed, was the opinion of Falconer and Busk, who came to the conclusion that the race who inhabited the Rock in prehistoric times used the Genista Cave as a burial-place.* Since the Glacial Period the Rock of Gibraltar has been raised 1,400 feet or more above the sea level, and the deposit in which the elephant's tooth was found at Tangier in Morocco, on the opposite shore, was an old beach raised about 15 feet above the present level of the Mediterranean.† Yet it is known that the Rock has for long been gradually sinking, so that at some future period this eyesore of Spain may disappear beneath the sea, and appear on the nautical charts of future generations as the Gibraltar shoal, to be avoided by vessels making for the wider Mediterranean of those days.‡

Fig. 175.—FUNERAL FEAST IN THE PALÆOLITHIC AGE.

* Busk: "Quaternary Fauna of Gibraltar," *Transactions of the Zoological Society*, 1877, and report in Sayer's "History of Gibraltar" (1865); Falconer: "Palæontological Memoirs," Vol. II., p. 554.

† On this subject the reader should consult a paper by Mr. Maw in *The Geological Magazine*, Vol. VII., p. 548.

‡ Lieut. Brown: "The Geology of Gibraltar" (*Proceedings of the Royal Artillery Institution*, 1866, p. 301).

In connection with this matter and what has been already said regarding secular rise and fall generally (Vol. I., pp. 167–177), it may be as well to remark that apart from those which were destroyed by the glacial ice-sheet and by subsequent denudation, many pre-historic remains of the European shore-dwellers must long ago have vanished, owing to the wearing away and sinking of the coast on which they dwelt, or of the caves in the cliffs in which they huddled, as to this day do some gipsies near Wick (Caithness), in a condition of filth and savagery comparable to anything which the cave dwellers could have exhibited.*

In the year 1887 the displacement of a mass of sand brought to light a forest just opposite St. Malo, at the foot of the cliffs of St. Enogat and St. Lunaire, which must have been buried fully twenty centuries ago. The progress of this sinking of the French coast during the last 2,000 years is clearly shown in an old map found at the Abbey of Mont Saint Michel. Within seven centuries as many as seven parishes are said to have disappeared by the subsidence of this region, and the forest now brought to light is supposed to have extended to beyond Mont Saint Michel. In the Bay of Douarnenez there is known to have existed in the fifth century a flourishing town called Is, the scene of the famous tragical legend. Even now, at low water, may be seen the old walls of Is, which are called by the Celtic-speaking Bretons Mogber Greghi ("wall of the Greeks"). The people of the country pretend that they can sometimes hear the old church bells of the submerged city ringing with the motion of the current, a myth of which M. Renan makes so pretty a use in his "Souvenirs."

It has been estimated that the gradual sinking of the soil of Brittany, Normandy, Artois, and some parts of the coasts of Belgium and Holland, is at such a rate that in about ten centuries all the Channel ports will be destroyed, and Paris itself will have become a maritime city. In another ten centuries it is predicted that the French capital itself will have become entirely submerged, excepting, perhaps, that the tops of the Pantheon, of the Arc de Triomphe, and other such monuments, may be discernible at low water by the people who will then be living. If this is not a specimen of the scientific use of the imagination, the prospect will afford some consolation for the loss of Gibraltar, though, indeed, when it has disappeared beneath the sea, there will be then no strait to command, and no Algesiras to frown at the hated "cuerpo" (Vol. I., p. 41, Fig. 15).

The Gibraltar caves—like most of those elsewhere—seem to have been occupied by various races at different periods, Roman remains being even among the relics found in that of St. Michael, a grotto, which was known to Pomponius Mela, a geographer of the Augustan Age. They were doubtless utilised for various purposes—refuges, dwellings, cemeteries; and the fact of the entrance to most of them having been so long closed that they have only been discovered during excavations for other objects, proves the antiquity of the races associated with them.

In many caves the remains are covered with thick deposits of stalagmite droppings from the limestone, which must have taken a long time to form, though it has preserved the relics in a very perfect manner. Sometimes from the heterogeneous mass of bones having been gnawed, the holes seem to have been the dens of wild beasts, subsequently taken possession of by man, while into others the remains appear to have either fallen from above or been swept by some flood, possibly produced by the melting ice-cap.

A discovery reported in a Wyoming (United States) newspaper in the year 1888, may, perhaps, suggest another manner in which some of the bone caves have received their contents.†

* At Tetuan, in Morocco, caves or hollows similar to those of Windmill Hill Flats in Gibraltar are used as workshops by the tile makers. In a garden a short way from Campamento, near Gibraltar, in an artificial cave extending a long way under the hill, a grave containing rude implements, chiefly of stone, was discovered some years ago.

† I have ascertained through inquiries directed to Laramie and other places in the Territory, that though my correspondents cannot vouch for the exact

Some men looking among rocks for their sheep noticed a crevice leading into a basin in the solid rock which was about forty feet in diameter at the top, and shaped like the upper half of an hour-glass. One of the men thought he would go down into this basin and see what it was like, when he observed another inlet close by which seemed to offer easier passage. On walking round the corner of the rock he was confronted with a "mountain lion" or cougar (*Felis concolor*), which on being shot by another of the party, rolled to the bottom of the basin and disappeared. On search being made, it was discovered that the bottom of the basin was a hole about twenty feet in diameter, opening into a cavity beneath, into which the beast had tumbled. On descending into this curious cavern, the explorer found himself in the lower half of an hour-glass-shaped hole in the rocks. The floor, which was of sandstone, was forty feet across, and the sides sloped upward and inward to the neck dividing the lower half from the basin above. It would be impossible for a human being or beast of any description once in there to escape without aid. In this cavernous room lay the dead mountain lion, but he was not alone. Nine more mountain lions, of the largest size, which had so recently fallen in that their hides were still whole, lay about, while the hole was filled from one side to the other with bones of almost every species of animal known on the plains. They had fallen into the trap formed by Nature, or crept into it for shelter or in search of food, and being unable to get out had died of starvation.

Discoveries in Open Strata.—Equally numerous are the discoveries in open beds—the finds in löss, gravels, and peats. The late M. Boucher de Perthes, as early as 1847, drew attention to the association of rudely-wrought flint implements with bones of the mammoth, rhinoceros, cave bear, and stag, in the diluvial deposits of the Valley of the Somme, between Abbeville and Amiens, and near St. Acheul, without being able to attract for his discoveries the notice they deserved.

However, he lived long enough to experience the satisfaction of being able to excavate, in 1873, at Moulin Quignon, near Abbeville, a human jaw-bone, besides stone hatchets, and of knowing that, in the same year, an international congress of professional archæologists confirmed the genuineness of his discovery. The flint axes and knives of the St. Acheul type (Fig. 136), of which thousands have been dug up, exhibit no trace of artistic workmanship, no polish or ornamentation, and represent the first and lowest stage of human skill in the making of weapons and tools. They were Palæolithic weapons, so rudely chipped (Figs. 191, 1-3) that it requires some practice to detect their human workmanship. But as Boucher de Perthes puts it, they were the first essays of our rude forefathers. Without them, as without the perseverance by which these primitive efforts were improved upon, we should have neither our towers nor our palaces, nor any of those masterpieces which we admire in them. The first man who struck one pebble against another to give it a more regular shape gave the first blow of the chisel which produced the Minerva and all the marbles of the Parthenon.*

A later discovery was that at Eguisheim, near Colmar, in Alsace, where, in 1867, out of the löss of the Rhine Valley, a fragment of a human skull was disinterred, associated with bones of the mammoth and other Pleistocene animals. Besides these, the fragment of a skull was found as early, it is asserted, as the year 1700, together with remains of mammoths, near Cannstadt in Würtemberg. Quatrefages has named the oldest diluvial race of man in Europe — that of the so-called mammoth period—after this, the earliest find of its kind, "the Cannstadt Race." He describes it as a long-headed race, with very low and small skull (dolichocephalic [Fig. 172] and platycephalic).†

details, the facts given are, in the main, sufficiently accurate for my purpose.

* Boucher de Perthes: "De l'Homme antédiluvien" (1860).

† In this race the French anthropologists still include the Neanderthal skull, that of Eguisheim, the human

To the discoveries in peat belong especially the important one which was made in 1866 at Schussenried, in Upper Swabia at the bottom of a peat-bog. There lay, enclosed between strata of glacier clay, a vast heap of broken bones, broken bone and horn implements, and fragments of flint. The greater part of these osseous remains were those of the reindeer and the horse. Beside these, there were found bones of the bear, of the fox, of the wolf, and of the Norwegian glutton (*Gulo borealis*), and of other animals now confined to the North. Fraas explains the formation of this heap, which contains only refuse, rightly, no doubt, when he assumes that there is at present a peat-bog where a lake existed in former times, on the shores of which dwelt men who threw the refuse of their dinners into the water.

Amongst this refuse were well-preserved mosses (*Hypnum sarmentosum*, *H. aduncum* var. *greenlandica*, and *H. fluitans* var. *tenuissima*) which are to be found nowadays only in the extreme north or on the Alps. The discoveries at Schussenried and elsewhere, place us evidently in a period in which a northern flora covered the soil of Upper Swabia, and northern — almost Polar — animals inhabited the tablelands, and during which glacial period Man already existed.* In the "leaf coal" or peat beds of Wetzikon (Canton Zurich) a kind of hurdle work, formed of sharpened fir-branches which are bound together by bark of trees, has been discovered.

According to the opinion of Professor Rütimeyer, there is no doubt that the specimen found is genuine. Yet this leaf peat of Wetzikon belongs to one of the interglacial glacial periods. The discovery, therefore, proves that Man already existed before the glacial formation in Switzerland attained for the second time its extraordinary development.

Prehistoric Races.—The discoveries in the French and Belgian caves have furnished the principal materials for the characterisation of the races which lived during the so-called reindeer period; that is, during the earlier Pleistocene age. At this time the mammoth and the cave beasts of prey were still indeed in existence, but the reindeer greatly preponderated, and was, together with the horse, the principal food of the people that inhabited Central Europe.

The most important of the caves in which these discoveries have been made are the following:—

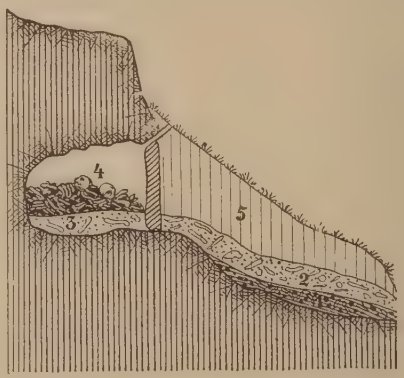


Fig. 176.—SECTION OF CAVE BURIAL-PLACE OF AURIGNAC (HAUTE GARONNE), FRANCE.

1, Ashes and charcoal with broken and cleft as well as calcined bones of existing and extinct animals; 2, Similar layers with only a few scattered cinders; 3, Layer of made ground with human bones and bones of extinct and existing animals, and many works of art; 4, Soil containing seventeen human skeletons; 5, Later accumulation of humus and talus of rubbish washed down from the hill above.

First on our list are the caves of Aurignac, a little town on the northern declivity of the Pyrenees in the Department Haute Garonne (Fig. 176). A workman discovered this cave in 1852; when putting his arm into a rabbit's hole, to his surprise, he brought out a human bone. On digging farther, he found a slab of sandstone which covered the entrance to the cave or cleft rock; and on removing this slab of sandstone he came upon so many human skulls and ribs, that fully seventeen skeletons of men, women, and children, which

jaw-bones from Naulette in Belgium, the skulls from the Pleistocene beds of Clichy and Grenelle, near Paris, the human remains from Arcy sur Eure (Yonne), from Mount Denis in Belay (Haute Loire), from Olmo in the Upper Valley of the Arno, near Arezzo in Tuscany, and from the caves of Gibraltar. It is, however, very doubtful whether the skull found at Brxx in Bohemia, which is sometimes considered to be assignable to this category, belongs at all to the Pleistocene period.

* Fraas, *Comptes rendus du Congrès d'Anthropologie*, 1869, p. 286.

were only covered with a little earth, appeared one after the other.

This discovery created an immense sensation, and, as the rumour spread that a gang of coiners existed who had murdered many men and had buried their dead bodies in this cave, the enlightened mayor of the place considered it his duty to have the discovered skeletons buried again as quickly as possible in some other place.

This remarkable find was therefore, to a large extent, lost again to science. Lartet found in the front part of the cave, when he visited it in 1861, a kind of rough fireplace, and round about it, buried in a thick heap of ashes and charcoal, together with bones of mammoth, rhinoceros, cave bear, cave hyæna, great elk, and numerous bones of reindeer, bison, and horse, lay worked pieces of reindeer and stag horn, and many tools roughly formed of bone and flint. As the buried skeletons could not again be discovered, it was only possible to ascertain about the men who once lived, interred their dead, and celebrated obsequies here, that they were of small stature, and belonged probably to a short-headed (brachycephalic) race (Fig. 173). Another important discovery was made in the cave of Cro-Magnon, on the banks of the Vézère (p. 246), in 1868. Five human skeletons, amongst them that of an old man and of an old woman, were found, which supplied the materials for the characterisation of the so-called "Cro-Magnon race." The skulls, regularly formed throughout, are dolichocephalic, with large prominent forehead and high arched crown (Fig. 172). So large are they that their capacity, according to the judgment of the French anthropologists, is, at the least, equal to that of the Parisians of our time. The profile presents a good facial angle, and the principal bones indicate a tall and robust figure.*

* The French anthropologists consider that the Engis skull already mentioned, which was found in 1833 by Schmerling in Belgium, and also two skulls unearthed in 1867 in a cave near Bruniquel in France, and some other crania, belong to this Cro-Magnon race. The skeleton which was found in 1872 by Rivière in the red cave of Mentone (Baousset rossé) also is supposed to belong to this people.

A large number of bones of another race, very different from this Cro-Magnon people, were discovered by M. Dupont in 1866 in caves near the village of Furfooz, in Belgium (p. 246). This has been called the "Furfooz race" by the French anthropologists. The most important objects have been found in the Trou du Frontal cave (Fig. 177). This cave consists of a great front space, which was used, according to Dupont, for the celebration of obsequies, as here stone slabs and charcoal—that is, a kind of hearth—have been discovered. The

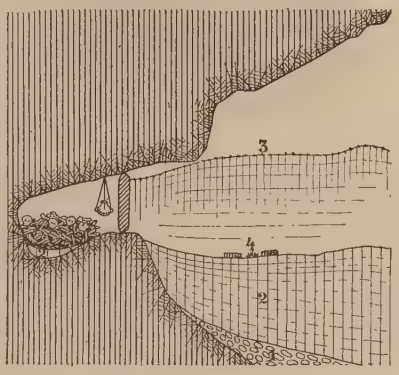


Fig. 177.—SECTION OF THE TROU DU FRONTAL.

(1), Gravel; (2), Alluvial silt, representing the older accumulations of the River Lesse, in the valley of which the cave is found; (3), Limit of later deposits; (4, Old hearth.

real burial-place is behind this spot, and was closed by a slab of dolomite. It is a small cavity—about three and a half feet broad, a little over three feet high, and six and a half feet long. Human remains belonging to at least fourteen individuals—men, women, and children—were found in this place thrown together in the greatest disorder. Dupont considers that the bodies were at first decently arranged, but that they were thrown into confusion by the action of water which afterwards penetrated the cave. Besides these skeletons, only the fragments of an urn with circular base, flint knives, and perforated Eocene shells were found. In the outer apartment, however, were lying, between the river silt and the stratified Pleistocene clay above it, thousands of flint knives, and remains of bears,

lemmings, wild boars, lagomys, horses, stags, chamois, reindeer, beavers, fishes, and birds, which were undoubtedly remains of food.

The examinations of Pruner Bay have shown the remains of this cave to belong

Fig. 178.—TCHUKCHI, FROM ARCTIC ASIA.

to a small, short-headed, mesocephalic, or brachycephalic race of very powerful build. The forehead is low and narrow; the arch of the skull not high.

To the same Furfooz race belong also, in all probability, the skeletons which have been found in the cave of Solutré, near Lyons. They have round brachycephalic skulls, and the animal remains associated with them indicate that the beings who dwelt here subsisted principally on the flesh of horses.

When we attempt to form from objects found in these caves some idea of the nature and degree of civilisation of the earliest inhabitants of Europe who lived contemporary with the mammoth, the cave bear, and the reindeer, in the heart of the continent, and who experienced the glacial epoch—at all events partially,—we can only say with certainty that they were savage hunters who, armed only with very rudely-worked stone weapons, obtained the necessaries of life arduously by a continuous struggle with wild beasts.

The Man of the Period of the Cave Bear and Mammoth lived still like the cave animals themselves, a true troglodytic life. His only weapons and tools—saving the club, and perhaps the sling, and some prepared pieces of horn and bone which probably served for both the scraping and smoothing of tanned skins—were simply roughly-wrought stone knives, hammers, hatchets, and spear-heads, sometimes of an oblong and sometimes of an oval shape, which had been broken and chipped from lumps of flint or hornstone. These are well exhibited in the weapons of St. Acheul and of Moustier in the Valley of the Dordogne (Figs. 136, 191, 1–3). He lived on the wild fruits of the forest and by hunting and fishing, and had no domesticated animals. His state of civilisation was about equal to that of the Australian aborigines. Nothing can be said with certainty about his ethnic characteristics, as the so-called "Cannstadt race" is not established with that precision which science demands.

A not inconsiderable progress is shown by the Man of the Reindeer Period during the earlier Pleistocene Age. His stone implements

Fig. 179.—TCHUKCHI WOMAN.

are more varied and of better workmanship; they are sometimes now, by means of chipping, converted into instruments with sharpened edges. (Type of Solutré, Fig. 191, 3). The utensils and instruments too, made of bones and pieces of horn, are now more delicately wrought, and show artificial embellishments (Fig. 158). Gay-coloured bright stones, teeth, and shells, were used as ornaments, pierced through and put together as bracelets, and necklaces. Red argillaceous iron-stone was

used for the painting of the body, vessels and pots were manufactured out of clay; and it is possible that there were even some domesticated animals. The horse and the reindeer, which were not tamed animals at that time, were the principal food of the Men of the Reindeer Period. Important improvements in the working of flints originated therefore with the people of this time. It was they who first learned to carve reindeer horns, bone, and ivory; and it was they who invented the arts of drawing, engraving, and sculpture—progress which manifests, at all events, a high degree of intelligence.

It is, as we have seen, two essentially different races to whom we must attribute this progress: to a long-headed one (the Cro-Magnon), and a short-headed (the Furfooz race). Their race characteristics and civilisation correspond closely with those of the people who are to be found at the present day in the north of the Continent, and in Greenland. It has therefore been affirmed, by Boyd Dawkins, that the long-headed Cro-Magnon race corresponds with the long-headed Eskimo* (Figs. 188, 189), and the short-headed Furfooz race with the short-headed Fins and Lapps. It has furthermore been conjectured that these Mongoloids and Turanians lived during the Glacial Period in Central Europe, and removed when it had passed, together with the Arctic animals, towards the north, and so made room for the immigration and dispersion of a new horde—the white or Aryan races, who arrived during the Neolithic Period. In Figs. 178, 179, 188, 189, 190 are engraved some types of modern races who are believed to live under conditions not widely dissimilar from those practised by some of the pre-historic savages described in this chapter.

The Later Stone Period, or Neolithic Age.—This period is characterised by "megalithic"—or great stone—memorials and by polished stone (*pierre polie* of the French), in contrast to the crudely-chipped flint weapons (*pierre taillée*) of the earlier Period. The megalithic memorials are constructed from great blocks of rock, preferably erratic blocks, which are set up singly, or of which several are erected side by side and one upon another, so as to represent a grave-chamber, or a place of offering (Figs. 180–187).

A simple stone chamber or stone table is the oldest form of megalithic tomb, and is called a Dolmen.† The word, derived from the Armorican or Low Breton tongue, is from *dol* (table) and *men* (stone). The Dolmen is sometimes called a Druid's altar. It was made of enormous blocks of stone, which form a grave-chamber, as if the inhabitants of Europe of that period had attempted to replace the natural caves by artificial ones for their dead. From four to six colossal rough-hewn stones form the supports, and one or two blocks, weighing sometimes from fifteen to twenty tons, the covering. The Dolmens were erected upon small natural or artificial hills, and were wholly, or almost wholly, visible above the surface of the earth (Figs. 180, 184).

A second form of these megalithic memorials is the stone chest grave with stone circle, or Cromlech (likewise an Armorican or Low Breton word, formed from *crom*, round, and *lech*, stone), called in the north "Huns' beds," or "Huns' graves." Around these graves are laid single great blocks, either in a circle or in a long ellipse. A stone circle surrounds often two stone chests (Figs. 183, 185, 186), but, on the other hand, several stone circles surround often only one grave. The stone graves are sometimes covered with earth, and sometimes not. The graves which are covered with earth often form large mounds, thirty or forty feet high. These are called Tumuli (Fig. 187). A stone-built passage leads from the outside into the grave-chamber, the so-called "Passage Building" and "Giant's Chamber" (Fig. 182).

Nearly akin to these megalithic memorials are the tall stones, standing often solitary or in circles—the so-called "Menhirs" (that is,

* This theory I have ventured to dispute on ethnological grounds in an inquiry into the "Origin of the Eskimo" (*Archæological Review*, 1888, pp. 237–253).

† It is not impossible that the table-looking tomb of stone, so often seen in our older churchyards, is a persistent tradition of the still more ancient Dolmen.

Fig. 180.—DOLMEN, CASTLE-WELLAN, IRELAND.

Fig. 181.—MENHIR, CROISIE, FRANCE.

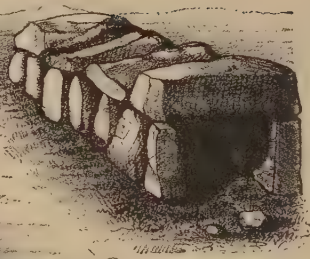


Fig. 182.—COVERED ROW OF STONES, FRANCE.

Fig. 183.—CROMLECH NEAR HALSKOV, DENMARK.

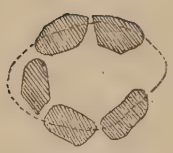


Fig. 184.—GROUND PLAN OF DANISH DOLMEN.

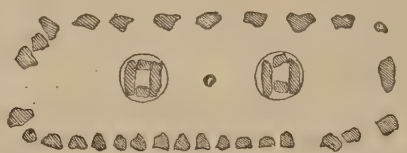
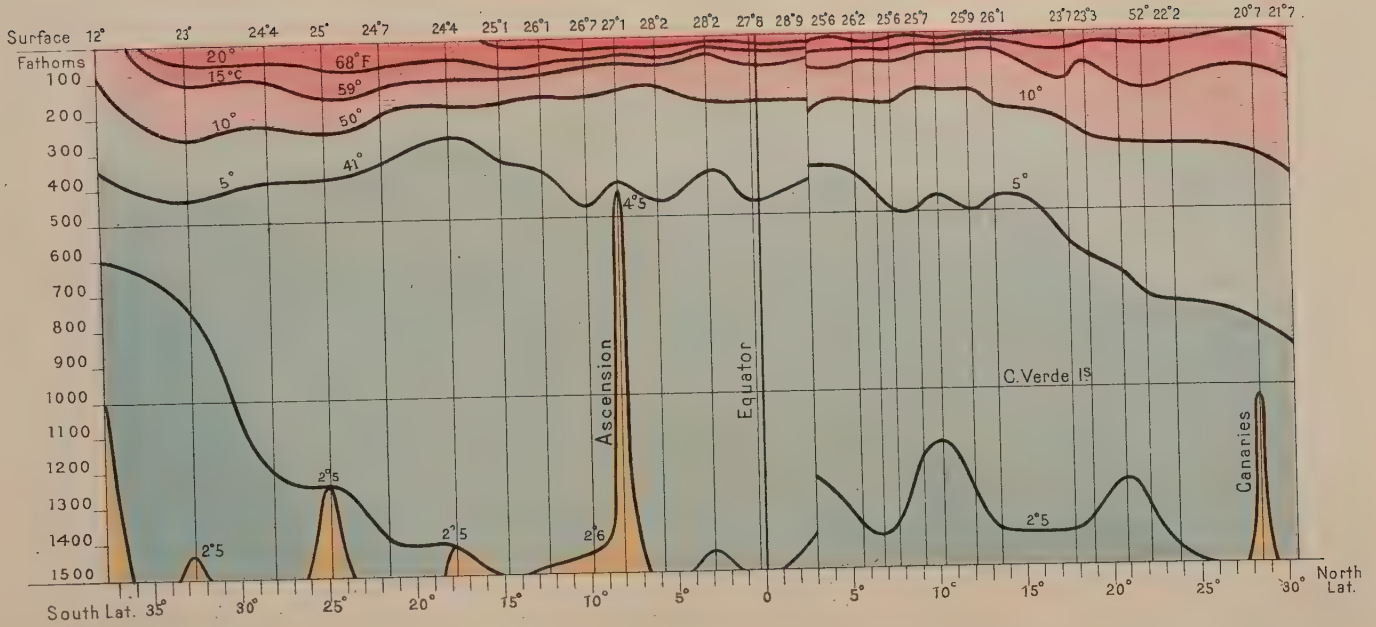


Fig. 185.—GROUND PLAN OF THE "LANGDYSSER" OF VALBIGAARDENS SKOV, DENMARK.

Fig. 186.—GROUND PLAN OF DANISH CROMLECH.

Fig. 187.—TUMULUS WITH STONE ENTRANCE NEAR UBI, DENMARK.



TEMPERATURES OF THE SEA IN THE NORTH AND SOUTH ATLANTIC

BETWEEN MADEIRA, CAPE VERDE Is, ASCENSION, AND TRISTAN DA CUNHA (IN DEGREES CELSIUS:)

(MARCH-APRIL 1876, JULY-AUGUST 1873.)

FROM WILD'S THALASSA BY PERMISSION OF MARCUS WARD & Co, LIMITED.

"long stones"), which may be regarded as memorial tablets (Fig. 181).

Megalithic grave memorials of the kind we have described are very common in the north and west of Europe. In North Germany, Denmark, Sweden, and Norway, they are

Fig. 188.—ESKIMO MAN, FROM GREENLAND.

constructed from erratic blocks. They occur in England, Scotland, Ireland (as at New Grange, on the banks of the Boyne, near Drogheda), in the northern and western parts of France, in the western part of Southern France, in the valleys of the Pyrenees, etc. They likewise occur in North Africa,*

throughout the Mediterranean territory, and eastwards as far as Palestine and India. In the central and eastern parts of France, in Central and Southern Germany, in Austria, Hungary, etc., no dolmens have up to the present time been authenticated, though these countries were doubtless already inhabited at the Dolmen-erecting period. In the east of Europe, in Poland, megalithic graves occur similar to the dolmens of the Stone Age.

The stone chamber or stone chest contains in all megalithic graves the remains of the dead. But already methods of burial differed. In Germany we find buried and burned corpses (the latter more frequently than the former). In Denmark burial was the exclusive practice. In England skeletons and urns containing the

Fig. 189.—ESKIMO WOMAN, FROM GREENLAND.

ashes of the dead are sometimes found together. In the dolmens of Northern France, unburnt bodies form the great majority. The

* On these and similar megalithic memorials, Fergusson's "Rude Stone Monuments" (1872) may be consulted generally, though with extreme caution, as many of Mr. Fergusson's theories, and even his "facts," are doubtful. Those of Algeria are described in many memoirs, the chief of which are Faidherbe's "Les Dolmens d'Afrique" (1873) and "Recherches anthropologiques sur les tombeaux mégalithiques de Roknia" (*Bulletin de l'Académie d'Hippone*, 1868, pp. 1–76); Bourguignat's "Histoire des monuments mégalithiques de Roknia" (*Souvenirs d'une exploration scientifique dans le nord de l'Afrique*, IV., 1868); Feraud's "Monuments dits celtiques dans la province de Constantine" (*Recueil des notices et mémoires de la Soc. Arch.*, de Constantine, 1863, pp. 214–234; 1864, pp. 108–132); and Letourneux, "Sur les monuments funéraires de l'Algerie orientale" (*Archiv. für Anthropologie*, 1868, pp. 307–320); and for those of Morocco with which Mr. Fergusson was not acquainted, Tissot and Broca, "Les monuments mégalithiques et les populations blondes du Maroc" (*Rev. d'Anthropologie*, 1876, pp. 1–24).

dead are usually in a sitting or squatting, rarely in a reclining, position; the knees touch the chin; the arms are crossed over the chest. And as if the builders of the dolmens had a foreshadowing of a future life, they were wont to put into the grave with the dead all those knives, saws, daggers, spear-heads, and arrow-heads), the varied shapes of which excite admiration in the museums of North Germany and Scandinavia, with the perforated stone hammers of diorite, syenite, basalt, serpentine, sandstone, etc. (Figs. 191 17, 18, 193, D, E).

Fig. 190.—SAMOYEDE FAMILY, FROM THE NORTH OF RUSSIA.

objects which were dear to them when alive—weapons, tools, ornaments, even food for the journey to their new home.

The stone implements of the Neolithic Period are more carefully and regularly elaborated, and are very often perforated and polished. From megalithic burial-places come the artistically-wrought and polished implements of flint (such as hatchets, chisels, But most valued of all were green or greenish rocks, the extremely hard nephrite, jade, and chloromelanite. The clay utensils of this Period were fashioned throughout by hand, and not on the potter's wheel, so that their form is often very unequal. Most of them were made of common unburnt clay, mixed with sand and charcoal-dust. They were only slightly burnt on the open fire, and show

no trace of glaze, and give no ring. The decorations are very plain. Straight lines, points, and zig-zag lines are the elements from which various patterns are constructed. Most of the vessels, with or without a handle, have a wide opening at the top. The tools and implements of horn, bone, and wood, are very varied. Needles, awls for leather work, knitting implements, heads of arrows, spears and harpoons, combs, knives, spindles, etc., occur. Tusks of bears and boars served as ornaments, likewise snail and other shells. Amber, too, is sometimes used (Fig. 191, 22). Whilst no trace of bronze or iron can be found in the dolmens of the north, single bronze objects have been found in French dolmens, and, in Algeria, even iron. The Dolmen-builders of the south appear therefore to have been acquainted with metals before those of the north. To the Neolithic Period belong also the "long barrows" of England, the "round barrows" or graves, dating from the Bronze Age or even from the Roman Period.*

The man of this Period pursued, in addition to hunting and fishing, agriculture and cattle-raising. He dressed in the fur of animals, spun linen, and lived in fixed dwelling-places, which he in all likelihood changed according to the season of year.

The most correct picture of the civilisation of the inhabitants of Europe during the Neolithic Period would probably be that of the Red Indians at the time of the discovery of America, or of the Polynesians before their connection with Europeans.†

Opinions differ widely regarding the nationality and race of the Dolmen-builders. The Celtic names of the megalithic monuments ought not to lead us to suppose that they were erected by Celts, as was at one time imagined. On the contrary, the Dolmen-builders were that nation which was subjected and dislodged by the Celto-Germans and the Celto-Gauls of the Metal Period. We are still less justified in supposing that these gigantic memorials were built by a special race of giants. Virchow observes rightly that only the graves, not the skeletons they contain, are gigantic. Small brachycephalic men sleep under the dolmens, especially in those of the north, who may have belonged to a Finno-Tshudic race, but remains of a great mesocephalic and dolichocephalic race of an Aryan type occur likewise. Many investigators believe in the existence of a separate Dolmen people. Some indicate the coast of Malabar, others the shores of the Baltic, as the starting-points of the Dolmen people. Others again have assumed that they came from the south, from North Africa, and immigrated northwards—in brief, were identical with the Berbers, the most widely spread of all the aboriginal peoples of that region. It is important to point out that both the Dolmen-builders and the Lake-dwellers domesticated animals and pursued agriculture. They must, therefore, have attained a degree of civilisation at all events much higher than the cave-dwelling troglodytes and reindeer men of the Palæolithic Period. But the existence of a separate Dolmen nation is more than doubtful. The map of the European nationalities would have appeared at the Dolmen-building period probably quite as much of a mosaic as now. The dolmens may have been built by Turanian and Aryan peoples who had been dwelling in Europe for thousands of years without any knowledge of the use of metals until—perhaps 2000 B.C.—they got gradually acquainted with them through eastern and southern influences.

The Kökkenmöddings.—To the earliest stage of the Neolithic times belong also the northern refuse heaps,‡ the so-called Kökkenmöddings, which occur along the coast of Jutland and of the Danish islands. They are small, wall-like mounds, often from 300 to 1,000 feet long, 100 to 230 feet broad, and 3 to 10 feet high, and consist chiefly of the castaway shells of edible shell-fish (oysters,

* "The Peoples of the World," Vol. V., p. 133.

† In Dawson's "Fossil Men and their Modern Representatives" (1880), and in Wilson's "Prehistoric Man" (1876), these points are brought out very clearly, while Mitchell's "The Past in the Present" (1880) demonstrates that a number of "prehistoric" traits and implements are still to be found in the Scottish Islands.

‡ "History out of Refuse Heaps" in *Science for All*, Vol. II., pp. 102–110.

cockles, whelks, mussels, and periwinkles) and the bones of consumed animals. Remains of the capercailzie and of the great auk, of the wolf, fox, and lynx, of a small dog (Lapland dog), of the beaver, the urus and red deer, of the roe and the boar, and fish-bones occur in them. These Kökkenmöddings (*Scoticè*, "Kitchen-middens"), therefore, go to prove that the Northern prehistoric races chose their habitations principally with a view to good hunting and abundant oyster beds. Of man-made tools these mounds contain only crudely-shaped stone implements, bone utensils, and potsherds.

Lake-Dwellings.—Lastly, the Lake-dwellings, or "Pfahlbauten," are of the greatest importance, for the study of the Neolithic Period. In the year 1854 Dr. Ferdinand Keller discovered the first Lake-dwelling* in the Lake of Zurich. Since then, many have been discovered in the Swiss lakes, in Bavaria, in Austria (in the Allersee, the Mondsee, and especially in the Laibach Moss [Fig. 30]), in North Germany, in England, Scotland, and Ireland. The Lake-dwellers resided on the water, building their huts on piles, a little

Fig. 191.—IMPLEMENTS OF THE STONE AGE.

1—8, Rudely worked (Palæolithic) flint weapons, France (1, Type of St. Acheul; 2, Type of Moustier; 3, Type of Solutré). 4-15, Stone implements and weapons, Denmark (4, Finely-wrought flint dagger; 5, Flint spear-head; 6, Flakes and core of flint; 7, Chisel; 8, Sharpener; 9, Round knife; 10, Finely-worked flint hatchet; 11-14, Flint arrow-heads; 15, Saw with wood handle). 16, Nephrite hatchet, with stag's horn setting and wood handle—taken from a Swiss Lake-Dwelling. 17-21, Polished stone (Neolithic) weapons. (17, Perforated Danish pickaxe; 18, Serpentine hammer, Bohemia; 19, French diorite polished hatchet; 20, Flint chisel, Denmark; 21, Hungarian hatchet of hornstone). 22, Amber ornament (necklace), Denmark.

* Keller: "The Lake-dwellings of Switzerland," translated by J. E. Lee (1878).

way from the shore. Thousands of trunks of oaks, alders, birches, beech trees, and pines were used for this purpose, and were rammed in which the numerous remains of clay utensils, tools, implements of stone and bone, spun-yarn, wicker-work and weaving, and of

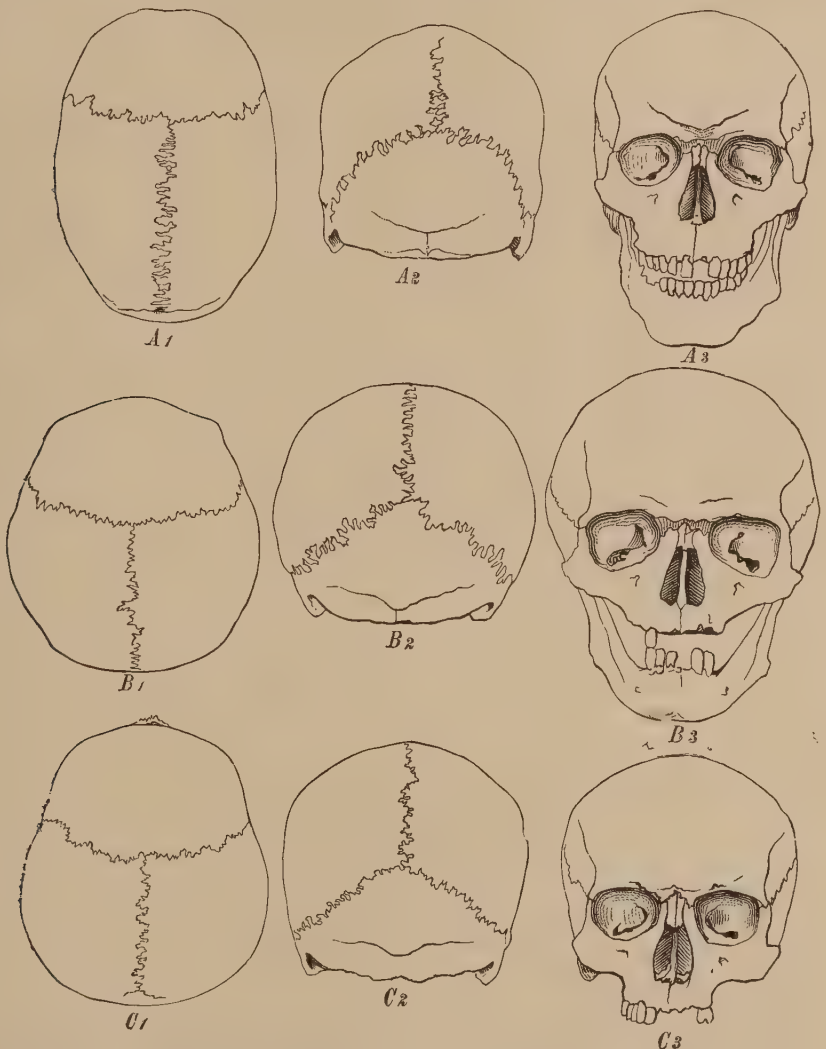


Fig. 192.—THE THREE CHIEF TYPES OF SKULLS AMONG THE PEOPLE OF MODERN GERMANY.

A, The German type (the long, oval, or dolichocephalic). B, The Turanian type (the round, short, squarish, or brachycephalic). C, The Sarmatian type (also brachycephalic). [*After Hoelder.*]

into the bottom of the lakes. On the original bed of the lake, and superficially covered by its later mud deposits, and by turf, there lies between the old piles that layer of silt the food of the past inhabitants have been found. The remains are principally those of the stag, ox, and pig, in addition to which, the roedeer, goat, sheep, horse, ass, dog, fox, wolf,

bear, bison, urus, chamois, elk, and beaver, with birds and fishes, are represented. But none of the characteristic Pleistocene mammals appear—even the reindeer seems by that time to have vanished from Central Europe. The corn (Egyptian wheat and six-rowed barley) appears as glittering charcoal. Of wild fruits, apples and pears, hazel-nuts and sloes, and seeds of strawberries, raspberries, and blackberries occur. Wrought flint knives and saws, artistically worked arrow- and spear-heads are found in numbers, with polished stone tools, hatchets and chisels, sometimes of nephrite and jade stone, and hammers, not infrequently with their original mounting of stag's horn (Figs. 191 15, 193). To the stone and bone tools are added, especially in the Lake-dwellings of Western Switzerland (in the lakes of Geneva, Neuchâtel, and Bienne [Fig. 34]) numerous objects of bronze and iron. The later Lake-dwellings, therefore, belong to the Metal Period.

In England, also, remains of early Man have been discovered in undisturbed Quaternary beds; for instance, at Crayford in Kent, on what was formerly an old shore of the Thames, flint flakes evidently struck off by the ancient spear makers. Associated with the flints, and also in beds above and below them, are tusks, teeth, and bones of the mammoth, rhinoceros, horse, ox, and deer, and some shells, all of living species, though two are not now found north of France, and one (*Cyrena fluminalis*) is at present living only in the Nile, some rivers of Tibet, and other portions of Central Asia. At various other portions of the Thames Valley similar finds have been made, and also at Salisbury and Fisherton (where, from beneath the skeleton of a mammoth, a flint implement was taken), and numerous other places, in most cases under similar conditions. These weapons are Palæolithic, rudely chipped, and seem to have been dropped in the old river gravels by the hunter in search of game, or when his coracle had been capsized, or his rude dwelling overwhelmed by freshets. Neolithic weapons are also found abundantly in England, but these have not the same geological interest as the others, as their position and character do not involve any such debatable questions as the older ones.*

Man in Europe: Metal Age.

When and where man first discovered the use of metals is a yet unsolved problem. Even during the earlier Stone period, as long, perhaps, as 2,000 to 3,000 years before our era, metal was in use. Copper and gold were probably the first metals utilised in Europe. Some time after this, bronze and iron began almost simultaneously to be employed. The art of working these metals may have been brought from Asia into Europe. The northern archæologists are, no doubt, right† in dividing the metal time into a Bronze and an Iron Age (or into an earlier bronze period and a later one, when the use of iron, too, was known). But bronze and iron are found mixed together in Central and South Europe, in most cases in such a manner as to make it difficult to separate a prehistoric Bronze from a prehistoric Iron Period.

To the Metal Period, understood in this way, belong the later Lake-dwellings of the Alpine district, principally those of Western Switzerland, the numerous remains of old dwelling-places (ash-fields, refuse heaps, the "Terramare" [from *Terra mara*, earthy marl])

* Evans: "Stone Implements of Great Britain" (1872); Brown (J. A.) "Palæolithic Man in Middlesex" (1887) and *Proc. Soc. Antiq.*, 2nd Ser., XI., pp. 211–215 (Ealing); *Ibid.*, pp. 161–166 (Wickham, Kent); Prestwich, *Philosophical Transactions*, 1859 and 1864; Boucher de Perthes: "Antiquités Celtiques et Antédiluviennes" (1847–60); H. and L. Siret: "Les Premiers Ages du Métal dans le Sud-Est de l'Espagne" (1888).

† The different periods of Prehistory show themselves, too, in the Danish peat bogs. Japetus Steenstrup found in the lower layers trunks of the Scotch fir (*Pinus sylvestris*), which has never been indigenous there in historic times, together with stone knives, such as were used by the eaters of shell-fish and hunters of the capercailzie, which is found only in pine forests. In the higher layers of the turf have been found trunks of an oak (*Quercus Robur var. sessiflora*), and, higher yet, appears another variety of oak (*Q. Robur var. pedunculata*), with bronze remains. And, at the present time, the oak is almost supplanted in Denmark by the beech, which indeed made its appearance there during the Iron Period, no trace of it being found in any of the Danish bogs.

in Upper Italy, of places of offering, of fortified places (Round wall, Long wall, etc.), and of burial-grounds. They are widely spread over the whole of Central and Northern Europe, and must be ascribed to those people of Aryan race (Celts or Gauls, Germans and Slavs) who inhabited Central and Northern Europe during the period which immediately preceded the Roman invasion and colonisation in the time of Rome's imperial power.

The richest discoveries have been made in the burial-places. Through the whole of Central Europe and as far as Asia, the most widely-spread forms of tombs of the Metal Age are those of the mound graves or tumuli. Quite as numerous as the names of these tombs in different places ("Gomilen" among the Southern Slavs, "Mohila" or "Mogila" of the Czechs, "Kurgane" in Poland and South Russia) are the styles of the buildings and of their interior arrangements. Some are made by simply throwing up the earth; others are made entirely of stones; others, again, are enveloped or roofed with stones. Bodies were buried as often as they were burned. When burned the ashes were put into urns. The grave is placed in the mound sometimes over and sometimes under the surface of the natural soil, and is often surrounded by stones, which are put together either in the shape of a stone cone or of a low stone chest. Very often the urn is only covered with a stone slab. Wooden coffins, too, made out of hollow trunks, are to be found. The tombs are always enriched by the addition of numerous articles, consisting of the ornaments, weapons, and tools of the dead, added to which are clay utensils (urns, vessels, shells), which, as remnants of animals' bones prove, must in part have held food. Some mounds contain only one grave; others number as many as ten to twenty in different parts of the mound. These latter may possibly be considered as family graves: they prove at least that one and the same mound had been used for considerable periods. The size of these tombs therefore is extraordinarily varied. All sizes occur, from scarcely noticeable mounds to others rising to a height of nine and fifteen feet, and a corresponding circumference. They are situated sometimes either singly in prominent places, or they are grouped together. Sometimes hundreds of mounds form a complete necropolis, the graves of which are situated indifferently on the plain, on the declivities of hills, and on table-lands.

In the Austro-Hungarian countries this shape of tomb was the most common during the Prehistoric Metal Period. In Bohemia, Moravia, Lower Austria, Styria, Carinthia, Carniola, Dalmatia, and likewise in Galicia (Fig. 164), Hungary, and Transylvania, mound-graves are found in great numbers. But besides the mound-graves occur numerous burial-places, the tombs of which must be designated as "flat-graves," because nothing distinguishes them from the surface of the earth.

One of the best-known grave-fields of this kind is the old burial-place on the Salzburg, near Hallstadt in Upper Austria, about which we may add a few words, on account of its great importance in prehistoric times. This grave-field lies about 1,200 feet above the level of the Lake of Hallstadt, and is, at present, partially beech forest, partially meadow-land. In the eighteenth century bronze objects had been found here, but they did not attract attention, as they were believed to be of Roman origin. But in 1846, during the construction of a road, so great a number of skeletons and bronze articles were brought to light, that in seventeen years 993 tombs were opened, and 6,084 objects preserved. And even yet important finds are being made.

Nothing on its surface attracts attention to this ancient burial-ground. It contains throughout flat graves from three to six feet deep. The soil has been prepared for the grave by being first levelled, then strewn with sand, and sometimes even covered with stones. After the funeral the grave was covered with a low heap of stones and a little earth. The graves show no trace of arrangement in rows and furrows. Two different kinds of funeral can be traced: the funeral without the burning of the body, and the funeral with burning. The first kind furnishes the so-called skeleton-graves, in which the

skeletons of the dead are more or less well preserved. The others are the so-called burned graves, in which only calcined bone remains of cremated bodies have been found. Skeleton and burned graves occur in about equal numbers. Rich and poor—men, women, and children—seem to have been without distinction burned or buried, and nothing reveals why now this, and now the other, form of interment was chosen.

The skeletons at Hallstadt lie usually on their back in an east to west direction, the faces turned east towards the sunrise. They rarely lie in other positions; and the arms are extended or crossed on the chest. These skeletons indicate a fine, tall, strong race, with dolichocephalic skulls of the pure German type. (Fig 192, A.)

The discoveries at Hallstadt have given their name to a special period of prehistory which is called the Hallstadt Period, and which dates during the last thousand years before the Christian era. To the same epoch belong the burial-places discovered in 1878 at Watsch, near Littai in Carniola, which are almost as rich in objects of interest (Fig. 139).

Lastly, a separate kind of burial-place are the urn-graveyards. They were noticed first in Lusatia, and on the banks of the Elbe in Northern Bohemia, and in Saxony. They are not wanting in more southern districts, and occur very often in Posen, East and West Prussia, Pomerania, and Hanover, and even (although with many modifications) in the Alpine countries. They belong to the last centuries before, and the first after, the beginning of our era, when the burning of the dead was universally practised.

Early Man in America, etc.

In various parts of Africa and Western Asia flint implements of the European type have been found in positions which would indicate great age. But, as they were not accompanied by organic remains which afforded any clue to their date, it is impossible to draw any conclusion from them. Moreover, in these countries implements of this kind have been used so recently, that it might be rash to infer much from their presence. In India, however, they have been found associated with the bones of an extinct elephant allied to the native species, and another elephant and a hippopotamus altogether extinct.

In North America the story of Prehistoric Man in his very early stages has been more fully traced,* though there is in the New World even more than in the Old a considerable difference of opinion as to the age of the deposits in which his remains have been found, and the conclusions justifiable from the facts ascertained. For instance, there are immense mounds of oyster shells, mixed with the remains of Man and his implements, on the Damariscotta River in Maine, covered over with vegetable mould and great trees. Yet in the neighbouring Salt Bay there are not at present any oysters, nor have they been numerous enough within the memory of man to make it worth seeking for them. Similar facts might be cited from other localities. The bones of extinct animals—the mastodon, the megalonyx, etc.—have been found, not only in the same deposits as the bones and implements of man, but in association with his remains. In various parts of the country works evidently of human manufacture have been found in gravels admitted to be Glacial, and in California mortars and even skulls have been discovered in gravels considered, at latest, to be Glacial, and by some geologists of eminence pronounced to be Pliocene.† These gravels are covered over with lava, so that, whatever may be their date, the physical geography of the country must have greatly changed since they were formed, for the period of the greatest activity of the volcanoes of the Sierra Nevada had not then ceased, or the river cañons and valleys been excavated, or, if

* De Nadaillac: "L'Amérique Préhistorique" (English Translation 1885); Southall: "The Epoch of the Mammoth" (1878); Dawson: "Fossil Men" (1880); Wilson: "Prehistoric Man" (1876); and a paper by A. R. Wallace in the *Nineteenth Century*, November, 1887, in which the entire evidence for the great antiquity of man in America is recapitulated.

† Skertchly, *Journal of the Anthropological Institute*, Vol. XVII. (1888), p. 332.

Fig. 193.—RELICS OF THE NEOLITHIC AND METAL AGES, PRINCIPALLY FROM THE LAKE DWELLINGS.

A, Stone Hatchet, from the Swiss Lake Dwellings; B, Stone Chisel, with stag's horn handle, from the Swiss Lake Dwellings; C, Stone Hatchet with double handle of wood and stag's horn; D, E, Serpentine Hatchet-hammer, from the Swiss Lake Dwellings; F, Flint Saw fitted into a piece of stag's horn; G, Flint Spear-head, from the Swiss Lake Dwellings; H, Arrow-head of Bone fixed on the shaft by means of Val-de-Travers asphalt (p. 191); I, Stone Arrow-head fixed by the same means; K, Arrow-head tied on the shaft by a ligature of string; L, Bone Bodkin, from the Swiss Lake Dwellings; M, Bone Needle; N, Bronze Sickle found at Chevroux; O, Harpoon of stag's horn, from the Swiss Lake Dwellings.

we admit the contemporaneity of the animal and vegetable remains, the present flora and fauna had not made their appearance. If these contentions are allowed, the Ohio mounds, which were old when the whites first saw them, though now generally attributed to the Cherokees, or the strange cliff-dwellings of Colorado, of the making of which the modern Moquis have not even a tradition, must be comparatively modern.

In South America research has not yet proceeded so far as to enable us to say whether the horses, tapirs, gigantic sloths, and armadillos, mastodons, etc., of the Pampa loams were synchronous with Man, and in New Zealand and Australia our knowledge is not less defective. In New Zealand there are good reasons for believing that the gigantic Moa or *Dinornis* (of which several species are known), with toe bones almost rivalling those of the elephant, was contemporary, if not with the present aborigines of that country, at least with some antecedent race. The chances, however, are that the ancestors of the modern Maoris saw it, as charred bones are found in connection with native ovens, while their traditions make frequent mention of it. This, however, does not prove much, since the freshness of the Moa's remains shows that it must have lived in comparatively recent times, and, indeed, the arrival of the Maoris in New Zealand from some Polynesian island is believed to date not much earlier than the fourteenth century.*

If we accept these data and the inferences derived from them, we must allow that Man existed before the Glacial Epoch. This he was quite capable of doing, since in Greenland—a country in much the same condition as glacial Europe of those days—a civilised people exist in what may be regarded as comparative comfort, with the inland ice (Vol. I., p. 374) and its products ever before their eyes.

There is, however, no good ground for holding that he existed in a much earlier period, far less in Miocene times, though if there is anything in the doctrines which have of late been so generally espoused, there ought to be a logical necessity for traces of Man, or of the semblance of Man, being discovered in the early Tertiary beds. Yet even the admission of his Pleistocene origin entails many grave corollaries. To use the words of a German writer—Dr. Ludwig Büchner—man existed in Europe at a time when "all the rivers had, at least in part, a different and more elevated course. England and France were not then separated by the Channel, but formed a single continuous mass of land, so that the men of that Period might have gone on foot from London to Paris, if those cities had then been in existence, and the proud Thames, upon whose bosom nowadays the ships of all nations rest, still formed a humble tributary of the affluent Rhine. The beautiful country of Switzerland was inaccessible to human foot: from the summit of the Alps to beyond the Jura, down to Geneva, and even to far-distant Soleure, it was buried beneath the chilly pressure of an enormous mass of ice, which bore upon its mighty back gigantic fragments of rock, and rolled them to places where they now look as if they had been transported by the hands of giants."

It must, however, be remembered that though the timidity with which these conclusions were at one time regarded has entirely vanished among educated and enlightened men, it is still a moot question, even with geologists, whether they are quite justified, or, in other words, whether Man is not in Europe a post-Glacial animal. In many cases there is a dispute regarding the age of the gravels, etc.; and, when this is admitted, regarding the contemporaneity of the remains; and lastly, when these two premisses are conceded, there must always be a doubt as to the number of years which have elapsed since the deposits containing such monuments of early Man were laid down. Hence, caution in accepting the extreme conclusions advocated by some writers is becoming more and more requisite, though at the same time it is idle to advocate views which would limit the existence of Man upon the earth to the puny period over which

* This subject is fully discussed in its latest aspects in Mr. Tregear's paper in *Journal of the Anthropological Institute*, Vol. XVII. (1888), p. 292.

written and traditional history extends. For if prehistory is infinitely longer, and more fragmentary, it is, perhaps, not much less authentic.

The Coming Man.

But now we have arrived at that period where Prehistory and History meet, and the geologist prefers to make room for the historian and antiquary. Race has succeeded race on the soil of Europe, during a space which we cannot count by centuries, but can only estimate at many thousands of years. Well-known authorities have estimated that an enormous number of ages have elapsed since Man dwelt together with the Mammoth, the cave bear, the great elk, or the wild horse, in Central Europe. But we have not as yet sufficient material for such calculations as will enable us to arrive at anything like certain results.

But Man, though the last of animal creations, is the greatest. His structure and his powers are far more wonderful than those of any species with which we have made acquaintance during our study of the deposits in which they are preserved. He is puny compared with many of them: yet he is the master of them all. His weak hands are no match for the fierce claws and powerful limbs of the beasts around him, and his naked body is open to the attack of brute enemies encased in armour. But the superior brain which he possesses has enabled him to forge weapons before which the hugest of his fellow-creatures have begun to disappear, and at the sight of which they fly in terror. No other creature has artificial implements; they must do the best they can with the thews and sinews bestowed on them, unless, indeed, the monkeys which throw stones and sticks are to be regarded as exceptions. Little by little he advanced, until he chipped flint into arrow-heads, knives, hatchets, hammers, and spear-points, improving by slow degrees on the rude palæolithic tools, until the polished ones to which he attained after the Glacial Period exhibit his increased experience (Figs. 191, 193). Then came those of metal, the quality of the metal improving as he grew older, until he reached the stage of rifled cannon and mitrailleuses. In his hands these arms have been powerful, both for good and evil. With them he has slaughtered his fellow-men. But he has also changed, with the most beneficent results, the features of the world, which he regards as his heritage. Rivers have been deepened and their course has been altered. Seas have been united, and continents spanned. Lakes have been formed where there was formerly dry land, and corn grown in spots where Man found the waters rolling. The rocks have been ransacked for metals, and cities built out of the mud beneath his feet, while the primitive coracle has given place to gigantic steamers, and sailing vessels scarcely less notable. But we are still to progress, and the Past must be considered only as a measure of the Future.

If Man has improved so markedly on the primitive age, is there any hope that his future intellectual greatness will be as much above that of to-day as to-day is elevated above the past? This is a fair dream of great-hearted men, but there seems some hope that it may be realised. At all events, there is no reason for doubting whether the intellects which are exceptional to-day will be the average of the future. We have seen nations and tribes decay, and be succeeded by others, and the future will witness the same ceaseless revolution. One goes and another takes its place, but the general progress of the race is upwards and onwards, and the human family may say of itself, in reference to those individual tribes which have disappeared—

> ——"Men may come and men may go,
> But I go on for ever."

In all Nature, as we shall see, there is a struggle for existence—the weakest goes to the wall, and the strongest moves onward. In civilisation we have observed this from the beginning. We have seen Man gradually getting wiser, and the stronger races overcoming the weaker. Can we dare to think that we have arrived at perfection? Our fathers in their vanity thought so; and their

fathers for a thousand years before ever deemed themselves pinnacles of human culture. Doubtless the builders of the Tower of Babel, after finishing that somewhat remarkable edifice, rather astonished at the acme to which human genius had attained, were inclined to sit down and weep tears of regret that there were no more architectural worlds to conquer. And yet mankind has done something since those days. Can we believe that the race will not attain still greater things, when we remember that in our own day man has stolen, Prometheus-like, the fire from heaven, and chained the lightning, which to his ancestors was only an instrument of Divine vengeance, in order that it may be the bondsman by which he annihilates time and space; that he has made the sun his painter, limning with a brush more skilful than that of Apelles; that he has weighed the stars as in a balance, and taken the waters under the earth and the treasured sunshine of vanished ages, to enable him to speed over land and sea; that he has gone far to solve the problem of cleaving his way through the air; and has so far warred against the forces of Nature as to go, heedless of wind and tide, where his fathers a few hundred years since did not venture in their rude canoes? Even his instruments of slaughter have attained such perfection that he thinks twice before engaging in a struggle. And yet the ancestors of the inventors of the magazine rifle, the torpedo, the turret-ship, and the hundred-ton gun, were, only a few centuries ago, woad-painted savages, who, with javelins and iron-pointed arrows, hurled back the headlong tide of battle brought to their shores by a race whose utmost mechanical skill centred in the short gladius, the bossed shield, the balista, and the quinquereme.

There is even reason for suspecting that the faculty of speech was imperfectly developed in early man. Yet recent discoveries, especially those of Collignon in Tunis, would indicate that the descendants of the people who made the rudest tools found in the earliest deposits are still living in that country.

We are stronger, as we are more intellectual and better, men than our fathers. The hands of the descendants of the Vikings who used to wield the Norseman's blades are now too large for their handles; the armour worn at the Eglintoun Tournament, by the heirs of the very men to whom it had belonged, had to be enlarged for the brawny limbs of the nineteenth century gentlemen. It has also been ascertained that the race is growing taller. In brief, the age of giants was not in the past; it is now—it is to come.

Hence, if the comparative anatomist has lowered our pride, in showing that we are not alone in this world, but have humble relatives, bone of our bone, and flesh of our flesh, he has, on the other hand, given much encouragement to every well-wisher of his species. For by the same law that the race has arisen from lowly beginnings —the law that in the struggle for existence the weakest shall die and the strongest live —we shall still go on to greater things, a view of the Evolution Theory that seems to be lost sight of.

All this is, no doubt, speculation. But it is speculation which is justified by the facts which we have unearthed. However, before we can arrive at anything like sound views on the subject we have a great deal more to learn.

There is a broad sea before us, and on the other side lies a new land. In the words of Sir Joseph Hooker, "along its broken shore, if not across it, science now offers to pilot us. Science, it is true, may never sound the depths of that sea, may never buoy its shallows, or span its narrowest creeks; but she will build on every tide-washed rock, nor will she deem her mission fulfilled till she has sounded its profoundest depths, and reached its farthest shore, or proved the one to be unfathomable, and the other unattainable, on evidence not yet revealed to mankind." And then the happy sons of man,

> ——"Through novel spheres of thought,
> Still moving after truth long sought,
> Will learn new things when I am not."

CHAPTER XV.

Geographical Distribution of Living Beings: Plants; Limiting Agents.

What the Preceding Chapters have led to—How far Ancient Distribution is connected with Modern Phyto- and Zoo-geography—General Facts connected with the Distribution of Plants—Mere Climatic Influences not Sufficient to Account for It—Temperature—Examples of Its Power in Limiting the Range of Particular Species—Moisture—Soil—Species which follow Particular Rocks and the Soils Formed from Them—This however less Dependent on the Food Furnished by these Soils than on Their Capacity for Retaining Moisture—Light—Subterranean Plants—The Struggle for Existence among Plants and Animals—Examples of This—War the "Natural Condition" of All Organisms—A Plant does not Live where it likes but where other Plants permit it to Live—Not a Tithe of the Species which come into Existence Survive—Effect of this Antagonism—Equilibrium of Species—Etc.

In the preceding chapters we have seen that from a state which there is every reason to believe was that of a molten mass, the globe gradually cooled until vapours could condense on its wrinkled surface, and rivers, lakes, and seas form. Then the work of denudation and erosion began by the wearing down of this surface of primary rocks, the sediment thus worn away being deposited in the sea, or in fresh water, where it hardened into the various kinds of sedimentary rocks with which we are acquainted. In this sediment were entombed the plants and animals characteristic of the ages during which it was laid down, so that imperfect though this record must necessarily be, it serves as a memorial of the successive floras and faunas which have peopled the Earth during the vast procession of ages which it has witnessed. As we go from the lower to the upper rocks—that is, from the older to the newer ones—we find their lithological composition more and more varied, owing to the fact that the materials upon which the geological agents had to act, were more and more varied as time advanced. Meanwhile, the rocks were not permitted to remain undisturbed, otherwise they would be at present all more or less horizontal. On the contrary, it is comparatively rare to find them not broken, contorted, or in some way tilted and altered, this alteration or metamorphism being more marked in the older than in the newer ones, and being due to heat and pressure exercised in various ways. The continual contraction of the earth through secular cooling causes the sedimentary beds to be pushed and raised into folds, which disturbances are among the primary agents at work in forming mountain chains. This folding, due to lateral pressure, dislocates the strata and causes earthquakes (though these may be traced to other causes also), and through the fissures thus formed molten matter rises from great depth in the shape of volcanic outbursts.

When we examine the plants and animals entombed in the crust of the globe, we find that they vary widely at different periods of its history, but that the nearer we approach our own times the more closely do they resemble the species now in the world, until in the newest Formations of all they are absolutely identical with the modern forms. It is, however, not until the latest stages of the Quaternary Period are reached that the distribution of the fossil and the recent plants and animals is the same. The floras and the faunas of successive epochs in the history of the Earth have been "differentiating and becoming more and more varied according to their degree of territorial separation"—to use Professor Ward's words. In brief, what was in Tertiary times one wide flora and fauna stretching over half the northern hemisphere, in the Quaternary epoch became broken up into several apparently distinct; and, on the other hand, no

single group of animals enjoys in the Cainozoic ages the same widespread distribution which so many did in the Mesozoic and Palæozoic epochs. For example, the Tertiary floras of the most remote regions of the world possess a striking resemblance among one another, wholly unknown among existing floras—as we see even in that of Australia, a country which from very remote periods seems to have had a group of plants and animals very much to itself.* What is more, we have seen that in tracing life from its remains in the oldest rocks to those embalmed in the newest ones, the earlier forms are of more lowly structure than the later ones. Backboneless animals precede those with backbones and the minute foraminifera—bits of jelly in shells—species with a more complex organisation.† By-and-by, reptiles succeed fishes, though the first reptiles are of the lower amphibian orders, and the first fishes the humbler cartilaginous-skeletoned types. Then come birds and mammals, though the first birds are lowly—feathered reptiles indeed—and the first mammals marsupials. We also find that many of these comprise in their own persons characteristics now distributed among various orders and classes. Last of all appears on the scene the loftier species, the crown of life being Man himself, whose implements and bones are found only in the uppermost deposits of all—those, in short, which have been formed in what may be regarded as the present epoch. In like manner the oldest plants are the humblest, those with the most complex structure only appearing in the newer Formations.

All this—and we are only summarising what has been more fully taught in the chapters which the reader has already studied—leads us to inquire, firstly, what has been the origin of all of these faunas and floras, where have they come from, and what led to the disappearance of their predecessors; and secondly, what is the relation between the ancient and the modern distribution of plants and animals; for it is evident enough, from the union and severance of islands with and from continents, and the various physical changes which the world has undergone, that there must necessarily have been some such relationship. Great Britain, for example, only dissolved partnership with the Continent after the modern floras and faunas had appeared. This severance must, therefore, have had a notable effect on the peopling of the British islands with their plants and animals.

The discussion of these two questions lies at the bottom of all biological and geological research; for it involves an inquiry, no matter how brief, into the now widely-accepted theory of the descent of modern plants and animals from pre-existing ancestors, which are those we find entombed in the rocks. However, in accordance with our usual plan, we may more usefully examine the facts on which this theory is based, before asking what grounds there are for entertaining it. This will, therefore, bring us to sketch the geographical distribution of the plants and animals now living on the earth, and the causes which are at work in limiting their range, or which are aiding, or have aided, their distribution from one part of it to another. Let us begin with the latter section of our subject—Epirrheology, as the systematists have termed it.‡

At one time, climate was supposed to account for all the varied distribution of plant life, and if any one was dissatisfied with this explanation, he was speedily silenced by being informed that he was trenching upon subjects which were neither good for man to know, nor which it was intended by the Master of Life that His creatures should pry into. Without stooping to refute such a very silly and impious dictum, we can only say that

* Von Ettingshausen: "Beiträge zur Kenntniss der Tertiärfloren Australiens" (*Denkschr. d. K. K. Akad. d. Wissensch.* Bd. XLVII., 1883); Ward: "Sketch of Palæobotany" (*Report of the United States Geological Survey*, 1883–4, p. 366).

† It may be remarked, with reference to what has been said regarding the similarity of the modern Chalk and the Deep-Sea Ooze, that Dr. Naumann, Director of the Geological Survey of Japan, has found in that country a "Radiolarian Slate" filled with remains of Radiolaria, and of great geological age, which proves that even in Palæozoic times a deposit was forming "corresponding to that of the mud from the deepest part of the ocean bed."

‡ Greek, *epirrheo*, I influence; and *logos*, a discourse.

soon botanists began to perceive that climate would not alone account for everything, and, indeed, for very little. As botanical voyages increased in number, and the floras of different countries became better known, it was seen that plants described under the same names were widely different, and that countries with very similar climates were distinguished by widely different groups of plants and animals. As early as 1810, Robert Brown* found that out of the 4,100 species of plants which he met with in Australia, only 167—mostly Cryptogamia—were found in Europe, and the vast majority of them in no other country, however similar or identical in climate. We now recognise the fact that very few plants are of anything like world-wide distribution. Some are extremely local. Others, like the pond weed (*Potamogeton*) and the hornwort (*Ceratophyllum demersum*), have a range almost from Pole to Pole. *Lotus* (trefoil), *Rubus* (bramble), *Plantago* (ribwort), *Oxalis* (sorrel), *Typha* (bulrush), *Nasturtium* (watercress), *Gnaphalium* (cudweed), and *Senecio* (groundsel or ragwort), are genera with a very wide distribution, but few, if any, of them range over the whole globe.

Humboldt was one of the first to perceive that most of these facts were due to laws more intricate than the mere influence of climate. Climate, he pointed out, will not explain why equinoctial Africa has no laurels, and the New World almost no heaths;† why calceolarias are found only in the Southern Hemisphere, or (speaking of animals subject to the same laws) why the birds of India glow with colours less splendid than the birds of the hot parts of America; why the tiger is peculiar to Asia, and the duck-billed Ornithorhynchus to New Holland.‡ He might have added that there is nothing in the climate of Southern California, Northern Africa, or North-West India, to prevent them from having the same vegetation as Australia, if temperature and other atmospheric influences were the agents concerned in the distribution of plants. Yet we know that all of these four regions are widely different as concerns their plants and animals.

We can conceive that bananas and palms (Figs. 200, 201) should, on account of certain peculiarities of structure, belong to the warmest regions, but we cannot explain on this theory of climate why Melastomas do not vegetate north of the parallel of 30°, or why no rose tree belongs to the Southern Hemisphere. Taking this popular notion of the all-powerful influence of climate into account, there is really no reason why the plants of the Cape of Good Hope should not be identical with those of Spain, or the trees of Oregon with those of Ireland. Nothing is more easy than to point out distant tracts of the world identical in climate, yet widely different in their vegetation. "In the Southern Hemisphere, if we compare large tracts of land in Australia, South Africa, and Western South America, between latitudes 25° and 35°, we shall find parts extremely similar in all their conditions, yet it would not be possible to point out three faunas and floras more utterly dissimilar. Or, again, we may compare the productions of South America south of latitude 35° with those north of 25°, which, consequently, are separated by a space of ten degrees of latitude, and live under a considerably different climate, yet they are incomparably more closely related to each other than they are to the productions of Australia or Africa under nearly the same climate."§

We have wider-stretching views now, and have learned that, though external agents exercise a powerful influence in limiting or extending the range of species, they are not the principal ones concerned, nor have they been the primary factors at work in causing the present distribution of plants and animals. First, however, let us take plants, since much which will require to be said regarding their geography applies equally well to animals. Moreover, it necessarily follows that plants

* "Prodomus Floræ Novæ Hollandiæ, et Insulæ Van Diemen," Vol. I. (1810).

† For long none were known, but of late the heather (*Calluna vulgaris*) has been found in Newfoundland and other parts of the New World. Its occurrence in Greenland rests on Giesecke's authority alone.

‡ Humboldt's *Personal Narrative*, Vol. V., p. 180.

§ Darwin: "Origin of Species" (6th Edition), p. 317.

must, in the majority of instances, have been the predecessors of animals upon the earth.

Fig. 194.—THE "BIG TREES" OF CALIFORNIA.
(*Sequoia* [*Wellingtonia*] *gigantea*).

But before doing so we may explain some words which will be of frequent recurrence in these pages, where, indeed, they have often appeared already. By the *Flora* or *Fauna* of a country we mean to express the assemblage of plants or animals found within the limits of that country, and the terms are just as commonly applied to a work descriptive of the plants or animals of a particular area.* The region occupied by or over which the *range* of a species extends is its *area*. The line at which a limit ceases to show itself is its *limit*. This limit towards the north is its *Polar limit;* towards the south, its *Equatorial limit*. A union of particular physical or biological circumstances constitutes the *station* of a plant, which is again different from its *habitat*, which is the particular place where it happens to grow, irrespective of the nature of the ground. By an *indigenous* species we mean a species which is, so far as we know, a native of the country where found, or, at least, that its foreign origin cannot be traced. Such a plant is the daisy, which, though found in more countries than one, and must therefore have originally, if the theory of the origin of plants here adopted be received, have migrated to some one or other of these stations, is still called indigenous in these countries when not known to have been *introduced* or *colonised* by man or otherwise. An *endemic* species, on the other hand, is a plant peculiar to the region in which it is found, and may have originated there—*e.g.*, most of the Australian species. Any plant which is very limited in its

* A new word introduced by Thurmann, but which has not yet received an English equivalent, is *tapis végétal*, to express a surface like a heath, covered with one or two species, so that the flora, which is in reality poor, has the appearance of richness; while another locality, like some sandy tracts, in reality rich in species (a rich *Flora*), has a poor *tapis végétal*.

distribution is called a *local* plant. The late Mr. Cottrell Watson* used some other terms which have got into use among botanists, and are very convenient. These are:—*Native*, apparently an aboriginal species, no reason existing for supposing it to have been introduced by man into the country where found; *denizen*, at present maintaining its habitat, as if a native which are certainly, or very probably, of foreign origin; and, finally, *casual* species are chance stragglers from cultivation.

The Influence of External Agents on the Distribution of Plants.

The distribution of the orders of plants is more independent of other orders than is that

Fig. 195.—THE GIANT "PEPPERMINT TREE" OF VICTORIA, AUSTRALIA (*Eucalyptus amygdalina.*)

species, without direct aid of man, but liable to some suspicion of having been originally introduced by human agency, whether by design or accident; *colonist*, a weed of cultivated land by roadsides or about houses, but seldom found except in places where the ground has been adapted for its production and continuance by the operation of man, with a tendency also in some of them to reappear on the shores, landslips, and what are called "waste places." *Alien* species are those

* "Compendium of the Cybele Britannica," Introduction (1870).

of animals, but it is more immediately and exclusively dependent on circumstances of soil, climate, and geological conditions than is that of other organised beings. These external conditions are chiefly:—Temperature, moisture, soil, light, and other plants, the influence of the last resulting in a "struggle for existence" among species.

Temperature.—Every plant must have a certain degree of heat in order to prosper, and it prospers in accordance with the amount received until this gets to the maximum, when it grows sickly in proportion as the

amount is exceeded, until finally it dies. The amount required differs for every plant. Some at the freezing-point suspend all development, and others—especially in cold or temperate countries—will bear many degrees below zero. One would think that this low temperature, by freezing the juices of the plant, would tear the cells asunder, and so destroy the organisation; but this cannot be, for often plants will be seen quite stiff with frost, and grow again as well as ever after being thawed, while others will be "nipped" when it was impossible that the juices could have been frozen.* The "zero" of life in different plants is very different, and, in general terms, it may be said to be sooner reached in plants of warm than of cold or Alpine countries or situations. Martins tells us that he observed *Soldanella* flowering under the snow, and in Arctic countries it is not uncommon in late springs to see saxifrages and other plants in bloom while their stems are covered with snow. Snow, however, keeps plants warm, and this fact ought always to be taken into account in calculating the cold which plants endure in certain countries.

Fig. 196.—THE POLAR LIMITS OF SEVEN TREES AND SHRUBS IN EUROPE. (*After Alphonse de Candolle.*)

1, Ash (Fraxinus excelsior); 2, Holly (Ilex Aquifolium); 3, Beech (Fagus sylvatica); 4, The dwarf almond (Amygdalus nana); 5, The silver fir (Picea pectinata); 6, The Pontic rhododendron (Rhododendron ponticum); 7, The dwarf palm or palmetto (Chamærops humilis).

Excess of temperature acts in much the same way as cold, and acts more from the injurious effects of the dryness which it induces than from the mere heat. The open woods of the Highland slopes called *Catingas* in Brazil, cast their leaves during the warm and dry season, just as other trees do in the cold season. For plants there is accordingly (1), a *useful* temperature, comprising all degrees between the minimum and maximum required or endured by that plant; (2), a *useless* temperature, below the minimum and above the maximum, ending in either direction in a *noxious* one. It is plain, therefore, that there exists a relation between the temperature and the life of the plant, and that "each plant is a kind of thermometer which has its own zero."

Humboldt, in order to show this, devised what are known as Isothermal † lines, or lines which touch all places which have the same annual temperature (*see* Plate). If temperature decreased in an exact ratio according to the distance from the equator, then these lines would run parallel to the lines of latitude. But this is not so, places different often 10° or 15° of latitude from each other having the same annual temperature. Accordingly, the isothermal lines describe a very sinuous course around the globe. Again, islands and places by the sea coast have a very uniform temperature, the summers being cool and the winters mild, while the interior of continents have hot summers and cold winters. Hence there is another series of lines called *Isocheimonal* ‡ and *Isotheral* § lines, expressing

* For a discussion of this subject, see Göppert, in *Botanische Zeitung*, 1870, No. 24; and Prillieux, in *Bull. de la Soc. Botanique de France*, 1869, t. XVI., p. 91.

† Greek, *isos*, equal; and *therme*, heat.

‡ Greek, *isos*, equal; *cheima*, winter.

§ Greek, *isos*, equal; *theros*, summer.

respectively, in the same way as Isothermal lines, the mean winter and summer temperatures, and which are more important as regards vegetation than the latter.* It is, furthermore, necessary, before exactly determining why this or that plant should be in this or that place, to take into account the temperature of the soil around its roots and the direct temperature of the solar rays on its aërial organs,—temperature usually calculated according to the readings of the thermometer in the shade, where it is very considerably lower than in the sun, to which the leaves, etc., are exposed.

Ranges of mountains, though they afford a temporary resting-place for the acclimatisation of migrating species,† have a remarkable influence in limiting the area of plants, chiefly on account of the plants being unable to endure the cold which they must be subjected to in crossing the summits, it being calculated that this is about 1° for every 340 feet of ascent. If the range is low or has gaps, plants will cross and re-cross easily. Prevailing cold winds also have an effect in lowering the temperature of a country and thus affecting the character of its flora.

The result of Alphonse de Candolle's researches‡ showed that (1), in no case does the limit of a species exactly coincide with a line of equal temperature for any one period of the year; (2), the limits of annual species on the plains of Europe cross one another with considerable frequency. The limits of perennial and ligneous species also cross each other in different directions, and both are far from being parallel when they do not thus cross. "This single fact shows us how much the lines of vegetation differ from the lines of equal temperature, for if we draw lines founded on the equality of heat at a certain season, they will be found to vary little from parallel lines. If we take some other season, such lines will appear nearly parallel with one another, though different, without doubt, from the preceding. Thus isochimenal lines will cross isotheral ones, but they will never cross each other, at least in a level country." De Candolle and Boussingault§ show that a great heat during a short period must produce the same effects on plants as with a less degree of heat during a longer period. The cultivators who would force or retard plants do nothing but combine the duration and the degree of heat. They thus succeed in producing the flower or the matured fruit at a given date. (Fig. 196).

However, this law is modified by the fact that each species requires, for each one of its physiological functions, a certain minimum of temperature. Not only is a temperature below freezing useless to plants, on account of the congelation of their juices, but even temperatures a degree or two above are valueless to a great number of species, and ought not to be computed among the temperatures available for a plant. Cultivate wheat in a climate constantly below 39° 20, and, though the plant will live long, and the product of the number of days multiplied by the temperature reach a high number, yet the stalk will not grow tall, nor will the flower be formed. We should be wrong to infer that 10° during ten days would have the same effect on all plants as 5° during twenty days. In both cases the sum of the atmospheric heat is expressed by 100°; but for species which do not vegetate below 42° 80, for example, the amount of 100° must be diminished by all the values between 41° and 42° 80, which occur in one of the supposed cases; while for those

* De Candolle, "On the Causes which limit Vegetable Species towards the North, in Europe, and similar situations" (Translated in *Smithsonian Report*, 1858, pp. 237-245).

† Mr. Wallace especially insists on this, though it is doubtful whether he does not, owing to the reason mentioned, exaggerate the facilities which mountain-chains offer to plants travelling from one region to another.

‡ MM. De Candolle and Baker have given names to plants according to their different degrees of heat-constitution. These are:—(1), *Macrotherms*, characteristic of the inter-tropical zone, and requiring stove heat for cultivation in the north; (2), *Mesotherms*, characteristic of the sub-tropical and warm temperate zones, and therefore requiring to be protected from frost; (3), *Meiotherms*, cool temperate plants, quite hardy in England; (4), *Microtherms*, plants of the Arctic-Alpine zone, and consequently needing protection from drought and full sunlight at sea-level in England.

§ "Économie Rurale," Vol. II., p. 659.

species which do not vegetate below 50°, if any such exist, the available heat would be reduced to 32°, or the freezing-point. Finally, De Candolle considers that the law he has brought out may be enunciated briefly in the following terms: "Every species having its polar limits in Central or Northern Europe, advances as far as it finds a certain fixed amount of heat, calculated from the day when a certain mean temperature commences, to the day when that mean terminates" (Fig. 196). There are a few apparent exceptions, but they are of no great importance.

Fig. 197.—THE GREAT-LEAVED LIME (*Tilia grandifolia*).

a, Flower and foliage; *b*, Fruit with broad stipule; *c*, Flower; *d*, Transverse section of the Fruit.

Alexander Buchan has shown that the ripening of crops does not depend on mean temperatures, but on high ones. The mean temperature of Scotland, for example, was, in August, 1860, 54° 4, and in the same month of 1864 also 54° 4, but in 1860 the mean of the highest day's temperature was 60° 8, while in 1864 it was 62° 5. This higher temperature in 1864 was the chief cause of the productive harvest of that year, and the lower day's temperature of 1860 was the chief cause of that year's deficient harvest, and yet the mean temperature of both years was the same. The growth and ripening of crops depend chiefly on the heat they receive from the sun—and this in Scotland is important, as they rarely receive more than what they just require to a minimum. As regards Great Britain, if the day's temperature rises occasionally to 65°, the amount of heat thus received by the grain crops may be looked on as sufficient for their growth up to the period of flowering; but after this a high temperature is required, and a frequent day heat of 70° is necessary to produce the finer qualities of wheat and barley. For other countries the temperatures essential to the successful cultivation of their staple products would require to be investigated, though, we believe, meteorologists are now almost at one in regarding vegetation arrested if the temperature falls any day below 40°. The following table (by

Fig. 198.—THE SMALL-LEAVED LIME (*Tilia parvifolia.*)

a, Flower and foliage; *b*, Fruit with broad stipule; *c*, The Flower; *d*, The pistil, or central organ of the Flower.

the late Professor Henslow, of Cambridge), shows the range of two grain crops and the mean temperature required to ripen them :—

Latitude.	Locality.	Winter Mean.	Summer Mean.	Annual Mean.	Crop.
Degrees.		Degrees.	Degrees.	Degrees.	
62·30	Faroe	39	51	45	Barley
70	Lapland ...	22	46	33	„
67·30	Russia ...	9	46	32	„
57·30	Siberia ...	0	60	32	„
58	Scotland ...	36	57	46	Wheat
64	Norway ...	23	59	39	„
62	Sweden ...	23	59	39	„
60·30	Russia ...	15	60	37	„
30	Cairo	57	88	72	„
22	Macao	64	82	73	„
22	Rio Janeiro...	68	78	74	„
29	Havannah ...	71	82	77	„
21	Bourbon ...	71	80	77	„

Göppert* has very properly remarked, that though the winter temperature of the Arctic Regions may fall as low as 40° to 70° below zero, there are very few plants which are subjected to this cold, most of them having stems so short that they are entirely concealed under the thick mantle of snow, where they do not experience a temperature much lower than about 28°.

The sensitiveness of plants to heat and cold is, indeed, evinced by the varying periods of the year at which they flower. The snowdrop and the crocus appear as soon as the winter's snow has disappeared; the hawthorn and our common fruit trees bloom later in the year; the ragwort and the St. John's wort do not put forth their flowers until near midsummer; the meadow saffron (*Colchicum autumnale*) appears in August, the aster and chrysanthemum at Michaelmas, while the black hellebore is a winter flower. On the other hand, the white dead nettle and the shepherd's purse may be seen in flower in almost any month of the year. All plants have different temperatures at which they will germinate, from the white mustard, which sprouts at the freezing-point, to maize, which refuses to show life under 48°, while some of the tropical plants require a much greater amount of heat. We also observe that the same plant will flower later or earlier according to the "lateness" or "earliness" of the season, and that, in different latitudes, a transplanted species will vary its period of flowering. It is likewise notorious that closely-allied species of the same genera have different times of flowering. Take, for example, the limes. In the same year, *Tilia grandifolia* (Fig. 197)

Fig. 199.—TREE FERN (*Alsophila armata*).

flowered on the 9th of June, *Tilia parvifolia*, (Fig. 198), nine days later, while *Tilia argentea* did not flower until twenty-two days afterwards.

Again, a cold which will have no effect on a holly or a fir, will ruin a Californian Wellingtonia (Fig. 194), or an Australian Eucalyptus (Fig. 195). It also follows that an annual plant can grow much farther north, and at a much higher elevation, than a biennial or a perennial one; since, in the first case, it requires only a summer temperature, while, in the other instances, it must be prepared to bear the cold of winter also. Owing to the distribution of sea and land in the Southern

* *Botanische Zeitung*, 1871, Nos. 4 and 5.

Hemisphere favouring a mild insular climate, the cold-fearing types (or "Macrotherms") of the torrid zone reach much higher latitudes than they do in the Northern Hemisphere. For instance, tree ferns (Fig. 199), avoiding the continental climates which are colder, affect the insular ones which, for the reasons given, are less severe. There is, for example, one species in Japan, another in the Bonin Isles (Fig. 223),

Fig. 200.—THE DWARF PALM (*Chamærops humilis*).

a, The tree; *b*, Lower portion of the trunk; *c*, Leaf; *d*, Flower.

another in Southern China, nine in the East Himalayas, while there are at least ten in extra-tropical Australia, eight in New Zealand, two in Lord Howe's Island, one in Raoul Island, two in Chili, and two in Juan Fernandez. But if the cycle of life is run rapidly, a country with a low mean temperature but a higher summer one, will be able to nourish plants which cannot grow in a region where both the winter and summer are milder. In Canada, where the January average is from 15° to 20°, good peaches and grapes are grown in the open air, and maize is cultivated in the fields, which cannot be done in England, though the average temperature of our most northerly winter month is no more than 32°. Again, cool temperate plants—wheat, barley, and sometimes oats—can be grown in India down to the tropic, because they can be sown and reaped during the coldest quarter of the year. With them are introduced a host of weeds of the same latitudes, which also run the cycle of their lives in the winter quarter.* But "in Sikkim, no European fruit of any kind, save the strawberry, comes to perfection; even the peach, the only commonly-cultivated tree, does not ripen its fruit; and the apricot, the most abundant West Himalayan fruit, is unknown. In Central Nepaul, farther west, apples, figs, peaches, quinces, and apricots, all ripen, but hardly arrive at perfection. Towards the interior of Kumaon, of which the capital, Almora, is 5,500 feet above the sea level, apricots and all the above fruits become abundant with the pear and cherry, and from Kumaon, westward, vineyards and large orchards form a conspicuous feature in the interior of all the valleys."†

Moisture.—Water, in relation to the growth and spread of plant-life, is of the utmost importance. It is necessary for food, and as a vehicle for the soluble materials on which the plant subsists. It keeps the earth moist, and, indeed, in the case of some aquatic species, it stands in the place of the soil to them. It is therefore a most powerful agent in the limitation and spread of species. It determines the Polar limit of those plants with which the wet climate of the North disagrees, and the Equatorial limit of others which require moisture for their growth. It ought, however, to be borne in mind that heat combined with moisture modifies, in some degree, the effects of moisture *per se*. It is doubtless, in part at least (Vol. I., p. 40), to the deficiency of moisture that the central regions of some countries, such as the steppes (Fig. 10, Vol. I.) and table-lands of Russia and Asia, and the prairies, pampas (Fig. 205), and desert regions of Africa (Fig. 11, Vol. I.)

* Baker: "Botanical Geography," pp. 49–58.

† Hooker and Thomson: "Flora Indica" (Introduction), p. 194.

Fig. 201.—COCOANUT PALMS OF PULO-PENANG, OR PRINCE OF WALES' ISLAND, STRAITS OF MALACCA. (*From a Photograph.*)

and of the interior of North and South America, are due. In the last case, the moist breezes from the Gulf of Mexico have exhausted themselves before they reach the prairie region, and the equally moist breezes of the Pacific are robbed of their humidity by the Cascade Range long before reaching the Rocky Mountains. Accordingly, the region on the west of the Cascade and its continuation the Sierra Nevada Range, is covered with luxurious forests, while the eastern side of the same range and the great waste between it and the Rocky Mountains are bare of forest, with only a few stunted trees and little verdure except by the side of streams. Both slopes of the Rocky Mountains, owing to the springs and rivulets from the melting of the snows, are clothed with bush and forest, but as soon as we go beyond the influence of this adventitious moisture, the treeless tract commences until we come within the influence of the Atlantic or Pacific Oceans again.* Some plants, like willows and alders in the north, require a great deal of moisture, and never thrive far away from water or wet ground. Others, again—like the cacti (Figs. 202–204), the eucalypti (Fig. 195), and the extraordinary *Welwitschia* (Figs. 206, 207) of the arid region of South Africa—can get along with scarcely any moisture.

Fig. 202.—THE COCHINEAL CACTUS (*Nopalea coccinellifera*).

Fig. 203.—THE MELON CACTUS (*Melocactus communis*).

There are, indeed, entire floras of this

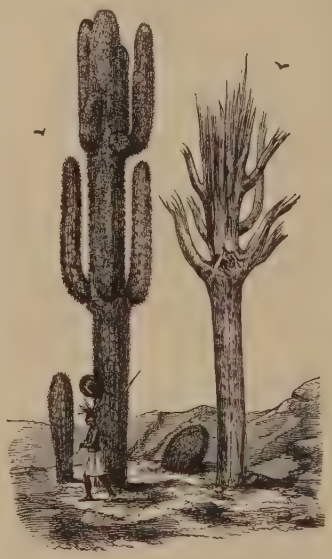


Fig. 204.—THE GIANT CACTUS (*Cereus gigantea*), WITH TWO YOUNG PLANTS IN DIFFERENT STAGES OF GROWTH.

"Xerophilous," † or dry-climate-loving character, such as those of the Sahara, Southern California, Southern Angola, Central Australia, and the Atacama Desert (Fig. 1, Vol. I.). On the other hand, there are others—like those in which the ferns predominate—which are equally "Hygrophilous," ‡ or moisture-loving. Indeed, as Watson and Baker have pointed out, those species in the flora of Great Britain which are known as of the "Atlantic type" of distribution affect the west side of the island, while those of the Germanic type, being partial to greater dryness and cold, are fonder of the east coast.

Trees, again, limit the distribution of species in another way. The reckless cutting down of the timber in many countries has lessened the rainfall, the result of which

* On the causes influencing the geographical distribution of Coniferæ, the reader may be referred to a paper by the writer, "Die Geographische Verbreitung der Coniferen und Gnetaceen" (with map) in Petermann's *Geographische Mittheilungen*, 1872, Heft II.

† Greek, *xeros*, dry; *philos*, a lover.

‡ Greek, *hygros*, moist; *philos*, a lover.

Fig. 205.—AN ARGENTINE (SOUTH AMERICAN) PAMPA.

is that some once fruitful countries, like Malta, are threatened with becoming little better than deserts from want of water.* The rain, instead of sinking into the ground in a well regulated shower, sweeps off the surface in "spates," carrying with it the soil, until the slopes of a hill will be entirely denuded, and the valley below covered with the *débris*. In this way entire regions in Algeria, Morocco, Tunis, America, Austria, and other parts of the world have been seriously injured (Vol. I., p. 8).

Fig. 206.—COUNTRY IN THE NEIGHBOURHOOD OF MOSSAMEDES, SOUTH-WEST AFRICA (LAT. 14° 20′ S.), WITH WELWITSCHIA MIRABILIS, HOOK FIL. (*After Monteiro.*)

Soil.—On this subject M. Duchartre truly remarks that we have facts in abundance, but almost no two authors agree as to the bearing of these facts, which he has summarised as follows. Soils are usually divided into *calcareous* (limy), *silicious* (sandy), and *argillaceous* (clayey). That certain plants are characteristic of each of these soils is universally agreed, each plant finding in each of these soils the elements required for building up its frame more plentifully or alone. For instance, the sand carex (*Carex arenaria*), or the bent grass (*Elymus arenaria*) will prosper in sand, which, to most plants, is a very ungrateful soil, and will speedily stifle other species to which this nutriment is not agreeable, though in a clay soil these very plants would rapidly obtain an ascendency over them. *Equisetum* (horse tail) loves marshy places where silica abounds. The Cornish heath (*Erica vagans*) is found in Cornwall on serpentine, while in Scotland and Ireland broom rape (*Orobanche rubra*) is chiefly found on the roots of thyme growing on decayed traps and basalts. (1.) The following plants are usually considered especially characteristic of calcareous soils, though by no means confined to them:—*Polypodium calcareum*, *Gentiana cruciata*, *Anthyllis vulneraria* (kidney vetch), *Astragalus glycyphyllos* (milk vetch), *Helianthemum vulgare* (rock rose), *Pyrus Aria* (white beam-tree), many orchids, above all *Cypripedium Calceolus* (lady's slipper), *Ononis*

* On this subject see Milne Home, in *Jour. Scot. Meteorol. Soc.*, 1870, and Becquerel, in *Smithsonian Report*, 1869, p. 394, translated from *Atlas Météorol. de l'Observatoire Impérial*, Paris, 1867, and in *Mém. de l'Instit.*, t. XXXV. (1866), p. 491; J. C. Brown: "Forests and Moisture" (1877); Playfair: "Travels in the Footsteps of Bruce" (1882); Campou: "Un Empire qui Croule" (1886); etc.

(rest harrow), *Melampyrum* (cow wheat), etc. (2.) Of silicious soils:—*Carex arenaria*, *Psamma arenaria* (maram or sea mat weed), *Elymus arenaria* (bent) and many grasses,

Fig. 207.—WELWITSCHIA MIRABILIS, A PLANT BELONGING TO THE ORDER GNETACEÆ.

b, The long horizontal cotyledons or seed leaves; *S*, The stem descending into the earth. In the lower figure the cotyledons, having acquired a hard, tough, fibrous consistency, do not die away, but gradually split up into shreds. *bl*, Short flowering stalks, developed from the upper side of the woody mass.

Digitalis purpurea (foxglove), *Plantago maritima* (sea plantain), *Jasione montana* (sheep's-bit), and all those plants which are so commonly found on sandy soil as to have obtained the specific name of *arenaria* (sandy). (3.) Of clay soils:—*Tussilago Farfara* (coltsfoot), *Petasites vulgaris* (butterbur), *Arctium Lappa* (burdock), *Inula dysenterica* (fleabane), *Cichorium Intybus* (chicory), etc. However, M. de Gasparin has well observed that the plants of the second of these three categories indicate a subsoil impermeable and humid rather than a sandy one. For it is the nature of the subsoil around the roots which determines the conditions of life, since on this depends the capacity of the soil for gathering and retaining moisture, or the contrary, and causing coldness or excessive moisture about the organs which are exposed to these conditions. Hence the benefit of subsoil drainage. But the theory that the conditions of distribution of plants in a country are dependent on the chemical condition of the soil is subject to grave objections, and the lists of plants supposed to be characteristic of this soil and that soil are continually being diminished. Alph. de Candolle, taking the memoir of Hugo v. Mohl on the influence of the soil* as his basis, came, on comparing 755 species belonging to Switzerland or Austria with the facts furnished by a study of the flora of other parts of Europe, to the conclusion that out of 383 which are said to be peculiar to, or to have marked preference for, some particular soil, 26 alone remained in this list as not having been as yet found on soil derived from the decomposition of primitive rocks, and 31 on soil from that of calcareous rocks.

That the soil has, however, an influence on the distribution of certain species of plants is certain. The plants of granitic, micaceous, and trappean soils—especially the arborescent

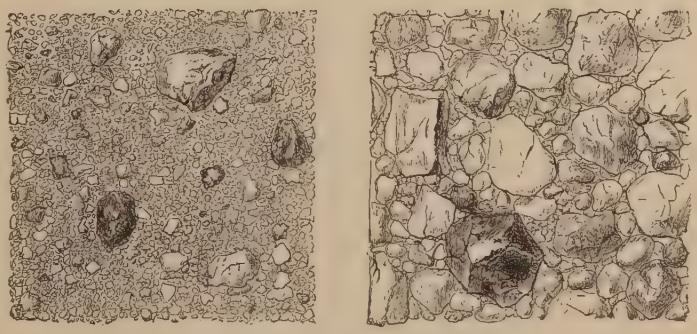


Fig. 208.—MAGNIFIED VIEWS OF SOILS.

A, Clay; B, Garden Mould. (*After Delessen.*)

species — are often markedly different. In

* "Ueber den Einfluss der Bodens auf die Vertheilung der Alpenpflanzen," 1838 (reprinted in *Vermischte Schriften*, pp. 393–428).

California the red wood (*Sequoia sempervirens*) grows only on metamorphic slates, and similar instances of certain plants being confined to certain Formations could be quoted. In Mexico, for instance, the appearance of the large "monumental" cactus (*Cereus giganteus*), is simultaneous with the change from sedimentary to volcanic formations.* In regard to this Schleiden has an eloquent passage which is altogether to the point:—

"The beautiful orchidaceous plant, the lady's slipper (*Cypripedium*), grows over all parts of the Swiss Fore Alps, where the soil is formed of the Alpine limestone; it accompanies the whole Swabian muschelkalk, and disappears suddenly when we come to the sand of the Jura and Keuper formations on this side of the Danube. It next makes its appearance on the muschelkalk of Thuringia, and comes down with that on the Werra as far as the neighbourhood of Göttingen, then leaps over the Bunter sandstone of the Lower Eichsfeld, the granite of the Upper Harz, and again gladdens the eye of the wanderer on the calcareous formations eastward of the Brocken. It is sought in vain over all the clay and sand formation of the Northern German plains, till, in the extreme north, it again shows itself at Rügen, where the chalk rocks of Arcona and Stubbenkammer lift their heads. On the western coast of France grow various insignificant-looking shore plants, species of *Salsola* (Saltworts), and *Salicornia* (Glassworts), from the ashes of which the inhabitants used to obtain soda.† When we travel from thence towards the East, we everywhere miss these little plants, even when searching most carefully, and merely one or other of them makes its appearance in such places where the soil is moistened by some salt spring. At last we arrive at the great steppes of the south-east of Russia (Vol. I., p. 29), which, in summer, are often covered with a thick crust of salt, showing them to be the ancient bottom of some dried-up sea, and here these plants are found growing in the same abundance and luxuriance as in the west of France. On the northern coast of Germany the little pale red maiden pink grows upon the arid sandstones, and is universally distributed over the sandy plains of northern Germany; but these are succeeded by the granite, clay, slate, and gypsum of the Harz, the porphyry and muschelkalk of Thuringia, and our little pink is not met with again till we arrive at the Keuper sand plains, on the farther side of the Main, surrounding the venerable city of Nuremberg. It extends south through the Palatinate, till the muschelkalk of the Swabian Alb again sets a limit to it; but it leaps over these and the whole Alpine region, and at last appears on the sandy soils of Northern Italy." Thus, we see these plants everywhere disdaining the richest soils in their range of geographical distribution, and confining themselves to perfectly determinate geognostic formations. In like manner, mainly owing to the absence of moisture, deserts limit the range of some species.

In Yorkshire, as Mr. Baker has pointed out, there are certain plants which follow the dry calcareous rocks from area to area, and around the intermediate belts of other strata. Among them may be mentioned the common columbine, the lily of the valley, the fly orchis, the bee orchis, the rock rose (*Helianthemum vulgare*), the Herb Robert (*Geranium sanguineum*), etc. The late M. Thurmann has given a list of species peculiar to the granitic Vosges and the calcareous Jura, though, as many of the species which he considers peculiar to either formation are in Britain common to all kinds of soils, his results are not to be received as of universal application.

Indeed, he admits‡ that the real influence of the soil on vegetation is, in nearly every case, its physical, and not its chemical, proper-

* Bell: "New Tracks in North America," Vol. II. p. 70.

† At one time large quantities of the ashes of these plants were imported into England under the Spanish name of "barilla," for making carbonate of soda, soap, and glass. Hence the popular name of *Salicornia*—"glasswort" in English, "glasschmalz" in German. But since the introduction of Le Blanc's process for obtaining soda from common salt (chloride of sodium) the importance of barilla has greatly diminished.

‡ "Essai de phytostatique appliqué à la chaîne du Jura et aux contrées voisines" (1849).

ties, particularly in the more or less complete disaggregation of its particles, and the avidity with which it retains or looses water (Fig. 208). For instance, he points out that sands have the same plants growing on them, whether they are composed of calcareous or of silicious particles. The truth is, the influence of soil on the distribution of plants is not dependent on its chemical or physical constitution alone, but on both acting in unison. Bentham shows* that if the distribution of any class of plants is more independent of other classes than that of animals, though more dependent on climate than the latter, it is also more complicated, and that, though fixed, there is no class in which the forms are not endowed with great facility of dispersion. The experiments of Lawes and Gilbert having shown how rapidly the numbers and constituent species of a mixed vegetation may be altered by the slightest change in the chemical ingredients of the soil, it is, perhaps, to this cause, operating in combination with the varied and complex means of distribution as to their greater antiquity, that the wider delimitation in the area of plants than of animals, originally noticed by Sir Joseph Hooker, must be attributed.†

Light.—That light has a marked influence on plants is self-evident, but it is not easy to separate it from that of heat. Plants of the shade will not prosper in open places, and *vice versâ*. Its effect is also manifest in the colours of the flowers. Alpine species, owing to the clearer atmosphere and the powerful reflection of the sun's rays off the snow, are very vivid in colour. (*See* Plate of Plants of the Alpine Region in Vol. I.) In plants which have a constitution so adaptable as to permit them to grow at very different elevations, we see the colour of the species, in some respects, changing with the difference of level. For instance, in the kidney vetch (*Anthyllis vulneraria*), the corolla is in one place very pale, in another pure white, and in another purple red. The influence of light is also exhibited in the marked difference which exists between plants of the open ground, with their vigorous aspect, their beautiful verdancy, and their aromatic odour, and those of dense woods, usually distinguished by quite the contrary characteristics.

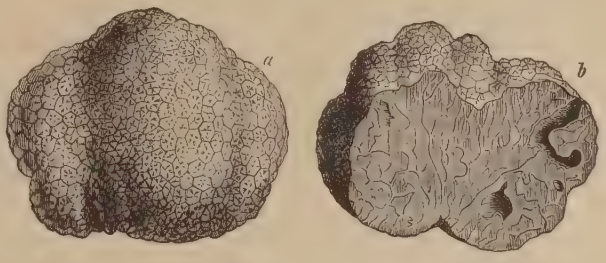


Fig. 209.—BLACK TRUFFLE (*Tuber melanospermum*). A SUBTERRANEAN FUNGUS.

a, Entire: *b*, Cut open.

Yet there is a distinct subterranean flora, consisting of between thirty and forty species of fungi, which shuns the light, living in pits, caverns, and mines, while the truffles—as every one knows—exist under ground (Fig. 209). Yet even they are very partial to calcareous soil, and prefer beech woods, though they are found amongst oaks also, and are not inimical to the society of a few conifers.

The Struggle for Existence.

This phase of Nature—with the name of which Mr. Darwin has familiarised the world, to an extent attained by few other scientific terms—must be accorded a leading place among the agencies concerned in limiting the range of species. They are permitted to live simply where other species will permit them. We have long known that in thickly-populated communities there is an actual, a fearfully realistic, struggle for existence. But there is another struggle, far more ancient, dating from the first appearance of created beings on the Earth, which has been raging ever since with a fury which, if quieter, is not

* "Presidential Address to the Linnean Society," 1869, p. lxvii.

† "Introductory Essay to the Flora of Tasmania," p. xii.

less keen than that with which we, of the newer creation, have been so long acquainted. As Dr. Maxwell Masters has put it very happily, the Wars of the Roses are a perpetual war.

An appreciation of the nature and extent of the struggle lies at the bottom of a right understanding of the laws which regulate the distribution of species, since the vegetable world presents the spectacle of a struggle going on at every place and everywhere at the same moment. No sooner does a plant take possession of a vacant spot than it is opposed by another invader, and, in the case of social plants, the new arrivals often hold the district to the exclusion of all others; a flora, poor in species, thus maintaining the place which might otherwise have been occupied by a rich one. Not only herbaceous, but woody plants, shrubs, and trees, are subjected to this competition for growing room. Linnæus calculated that if an annual plant produces two seeds which arrive at perfection (and no plant produces so few), and these in turn perfect each two, and so on in geometrical progression, at the end of twenty years the descendants of the original plant would number a million of individuals. It is reckoned that a single groundsel plant (*Senecio*) may produce 6,500 seeds, one of chickweed (*Stellaria*) 5,000, and one of shepherd's purse (*Capsella*) 4,500. Darwin* calculated that a single plant of an orchid (*Cephalanthera grandiflora*) produces 24,000 seeds, and the common *Orchis maculata* the prodigious number of 186,300, so that, in ordinary geometrical increase (did not the "struggle for existence" intervene), the great-grandchildren of a single plant would nearly (in the proportion of 47 to 50) "clothe with one uniform carpet the entire surface of the land throughout the globe." Yet this orchid was by no means widely distributed, the reason being that, with overcrowding and the preying of insects, very few of its enormous progeny ever reach maturity. There is, therefore, a struggle for existence. Mr. Darwin puts the whole subject admirably in the following passage in reference to the animal kingdom, but the same (*mutatis mutandis*) might be applied to the vegetable:—"We behold the face of Nature bright with gladness; we often see superabundance of food. We do not see, or we forget, that the birds which are idly singing around us mostly live on insects or seeds, and are thus constantly destroying life; or we forget how largely these songsters, or their nestlings, are destroyed by beasts of prey; we do not always bear in mind that, though food may now be superabundant, it is not so at all seasons of each recurring year."†

In England this is apparent. The American waterweed (*Anacharis Alsinastrum*)‡ was first recorded in Britain in 1847, though observed a few years earlier. Now it has spread with inconceivable rapidity over the whole land—though it has never yet been known to produce seed in England—to the extinction of the native species with which it comes into contact. Its spread into so many localities is doubtless greatly due to waterfowl. Yet in America it is not more troublesome than other weeds. The water crowfoot (*Ranunculus aquatilis*) generally disappears in due course when the *Anacharis* introduces itself. The "fringed water-lily" (*Limnanthemum nymphœoides*), Mr. Britten says, was quickly eliminated from a pond on Wandsworth Common, into which it had been introduced, when the *Anacharis* made its appearance, though previously, to all appearance, naturalised. The *Potamogeton*, or pond weed, seems, however, to be able to keep the *Anacharis* in check.

In some places this "water thyme" or "drain devil" is really impeding the navigation of canals and rivers—such as at Aylesbury and in the Cam. A plant of *Jussiæa grandiflora*, thrown out of the Montpellier Botanic Gardens into the River Lez, so speedily

* "Fertilisation of Orchids," pp. 344, 345. In the "Origin of Species" the subject is fully discussed. However, in this chapter facts are gleaned from a variety of sources, among others, from papers by Dr. Maxwell Masters and Mr. Britten and other observers, as well as from personal observation.

† "Origin of Species," p. 49. But as early as Pliny's day this struggle for existence was appreciated. ("Historia Naturalis," Lib. XV., Cap. 24.)

‡ The *Elodea canadensis* of Richard.

multiplied as to become an impediment to navigation, while *Aponogeton distachyum* is also getting naturalised in the same river. In like manner, a Chilian plant—*Galsinsoga parviflora*—is becoming acclimatised near Kew and Richmond since its escape from the Royal Gardens. *Veronica buxbaumii*, a native of Southern Europe and Central Asia, which first appeared in England in 1829, is now one of the commonest corn weeds; and an American balsam (*Impatiens fulva*) is equally at home. We know that these have been introduced, but in reality plants like the poppies, corn-cockle, pimpernel, red dead-nettle, fumitory, and most of the corn weeds, and even such plants as the chickweed, groundsel, shepherd's purse, and *Poa annua*, are, to a great extent, dependent on cultivation, and may have originally been introduced, though their origin cannot now be traced.

"I do not remember," Sir Joseph Hooker tells us, "ever having seen any of these plants established where the soil was undisturbed, or where, if undisturbed, they had not been obviously brought by man or the lower animals; and yet I have gathered the shepherd's purse in various parts of Europe, in Syria, in the Himalayas, in Australia, New Zealand, and the Falkland Islands." The same author points out that, while in uncultivated districts the proportion of annual plants is exceedingly small, in cultivated districts they are numerous; "and the farther we go from cultivation, roads, and made ground, the rarer they become, till at last, in the uninhabited islets of the west coast of Scotland and in its mountainous glens, annuals are extremely rare, and confined to the immediate neighbourhood of cottages." He continues: "It is usually said of some of the annual plants that they prefer cultivated ground, nitrogenous soil, and so forth, and this is, no doubt, true; but that they will flourish where no such advantages attend them a very little observation shows; and that they do not continue to flourish elsewhere is due mainly to the fact that, being annuals, their room is taken as soon as they die, and the next year's seedling has no chance of success in the struggle with perennials."

About one-fifth of the British plants are supposed to be naturalised species, many of them being dependent on agriculture for their existence. *Rumex Acetosella* (the sheep-sorrel) has been introduced with grain into nearly every colony, and in New Zealand it is spreading with singular activity, and would take possession of the land did not the farmer find that, in the struggle for existence, it cannot bear up against the greater vigour of the white clover, which soon kills it. This is taking advantage of "natural selection." Even the white clover—in one locality, at least—has its match in the cat's-ear (*Hypochæris radicata*), which has been introduced into New Zealand, where, in less than three years, excellent pastures were destroyed by it. In little more than forty years at least 180 European weeds have got thoroughly naturalised in New Zealand, and in the Northern United States alone 214 British plants have got introduced from Europe since that country was colonised, and are now settled as if "to the manner born."* The knot-grass is very common about New York, and the introduction of the Anacharis into Britain is paralleled by that of the Vallisneria into the Hudson, where, in the months of August and September, it almost stops navigation in many places. The watercress threatens to choke up the New Zealand rivers in the Province of Canterbury.† These may be taken as examples, though instances could be multiplied.

A grass—*Stipa textilis*—has invaded the plains of Southern Russia, and is rapidly displacing almost every other plant. Species introduced into India since its acquisition by the English now range from Cape Comorin

* In Asa Gray's "Manual of the Botany of the Northern United States," 260 naturalised plants are enumerated, belonging to 162 genera—and of these 162 naturalised genera, no less than 100 are not indigenous there. Out of 2,091 indigenous phanerogamia there are 321 European species (Gray, on "Statistics of the Flora of the Northern United States," in *Am. Journ. of Sc.*, 1856, p. 9). This bears out Alphonse de Candolle's idea, that floras gain by naturalisation, proportionately to the native genera and species, far more in new genera than species.

† Hooker in *Nat. Hist. Rev.*, 1864, p. 124.

to the Himalayas, and several plants, such as the milk thistle (*Carduus Marianus*), and a tall thistle, the Cardoon (*Cynara Cardunculus*) introduced from Europe, now clothe, almost to the exclusion of other plants, whole leagues of the pampas of La Plata and Uruguay.

Auguste Saint Hilaire mentions that in Brazil, around Sainte Therese, the European

Fig. 210.—EUCALYPTUS FOREST, WITH CASUARINAS (BEEF WOOD) AND TREE FERNS, AUSTRALIA.

violets, borage, fennel, and some geraniums are perfectly naturalised. The oat is very common in the pastures, and everywhere throughout the country we find the familiar mallow, *Anthemis* (camomile), and *Marrubium* (horehound) of Europe. A European *Myagrum* is now completely naturalised on the walls of Monte Video, and occupies the space between the city and suburbs. The flora of the American prairies is, as a whole, singularly susceptible to the inroads of civilisation. Even the grazing of cattle for a few years is sufficient to materially alter its character. The grasses dwindle in size and luxuriance, while the relative abundance of the other plants becomes materially altered. The breaking up or turning of the soil at once exterminates a large number of the previously dominant species, and the more hardy exotics usurp their places, the cereals, the cultivated grasses, and the noxious weeds of the Old World thoroughly crowding out the original occupants of the soil.* Mr. Gillman noticed, some years ago, that in a pool at Sandwich, on the Detroit River (Michigan), *Wolfia columbiana* had taken possession, driving out the equally tiny duckweed (*Lemna minor*), before quite abundant.

Mr. Darwin states that "the facts hitherto observed favour the supposition that in the struggle for life between the denizens of the Old continents and the New, the former are prepotent," and attributes this to "the longer period they have engaged in strife, and the consequent vigour they have acquired." At

* Allen, in *American Naturalist*, Vol. IV. p. 585.

Map showing the

DISTRIBUTION OF PLANTS

After O. Drude.

NORTH POLAR SEA
NORTHERN FLORAL REGION
Arctic Dist.
CENTRAL NORTH AMERICA
TROPICAL AMERICA
PACIFIC OCEAN
INDIAN FLORAL R.
Polynesia
Hawaii
Marquesas Is
Lower Archipelago
Sandwich Is
Galapagos Is
Juan Fernandez
Ambrosel
ANDES FLORAL R.
ANTARCTIC FLORAL R.
Falkland Is
Georgia
Bouvet
Tristan d'Acunha
St. Helena
Ascension
Azores
Canary Is
Cape Verde
MEDITERRANEAN
ORIENT
Arabia
Hadramaut
Socotra
Yemen
Zanzibar
Madagascar
Mauritius
Seychelles
Comoro Is
Maldive Is
Laccadive Is
East Africa
AFRICA
S AFRICAN FLORAL R.
SW Cape Col?
SE Cape Col?
INDIAN OCEAN
AUSTRALIAN FLORAL R.
Australia
Tasmania
New Zealand
Chatham Is
Auckland Is
Campbell Is
Antipodes Is
Kermadec Is
Norfolk Is
New Caledonia
Loyalty Is
New Hebrides
Solomon Is
Admiralty Is
Bismarck Archipelago
New Britain
Papua District
Caroline Is
Marshall Is
Philippines
Formosa
Japan
Bonin Is
Loochoo Is
Hongkong
Canton
Amoy
Shanghai
Yellow Sea
Corea
Sea of Okhotsk
Behring Sea
Kamtschatka
Okhotsk Coast
Aleutian Is
Hudsons Bay
Baffins Bay
Greenland
Iceland
Spitsbergen
Franz Joseph Is
New Siberia
Wrangel Land
Nova Zembla
North Sea
Baltic Sea
Europe
Middle Asia
Steppe
Aralo Caspian
West Turkestan
Mongolia
Tibet
CENTRAL ASIA
Middle Siberia
Arctic District
Northern Canada
Columbia
Montana
California
Mexico
Texas
Gulf of Mexico
Cuba
Haiti
Jamaica
Antilles
Barbados
Trinidad
Guiana
Amazonia
Brazil
Peru
Bolivia
Chile
Patagonia
Paraguay
Uruguay
Argentina
Tropic of Cancer
Tropic of Capricorn
Equator
Sahara
Nubia
Abyssinia
Guinea
Senegambia
Sudan
Nigritia
Lake Tchad
Congo
Angola
Cape Colony
Natal
Orange Free State
Transvaal
Zambesi
Nyassa
Zanzibar
Somali
Red Sea
Persian Gulf
Euphrates
Tigris
Mesopotamia
Syria
Palestine
Asia Minor
Black Sea
Caspian Sea
Aral Sea
Lake Baikal
Amur
Yenisei
Lena
Obi
Irtish
Ural
Volga
Dwina
Petchora
Kara Sea
White Sea
Baltic Sea
North Sea
Ireland
Great Britain
France
Spain
Portugal
Italy
Sicily
Sardinia
Corsica
Balearic Is
Malta
Crete
Greece
Turkey
Roumania
Hungary
Austria
Switzerland
Germany
Denmark
Norway
Sweden
Finland
Iceland
Faroe Is
Shetland Is
Orkney Is
Hebrides
Channel Is
Azores
Madeira
Canary Is
Cape Verde Is
Bermudas
Bahamas
Jamaica
Haiti
Cuba
Antilles
Barbados
Trinidad
Guiana
Amazonia
Brazil
Peru
Bolivia
Chile
Patagonia
Paraguay
Uruguay
Argentina
Falkland Is
Georgia
Bouvet
Tristan d'Acunha
St. Helena
Ascension
Galapagos Is
Juan Fernandez
Ambrosel
Sandwich Is
Hawaii
Marquesas Is
Lower Archipelago
Polynesia
Hawaii
Fiji Is
Samoa
Tonga Is
Society Is
Marquesas Is
Lower Archipelago
Sandwich Is
Galapagos Is
Juan Fernandez
Ambrosel
Tristan d'Acunha
St. Helena
Ascension
Azores
Canary Is
Cape Verde
Madeira

all events, these facts show us that species are not in all cases placed by Nature just in those situations which are most advantageous to them, some plants attaining more vigour in localities where they have not been settled a hundred years than in their original homes. In the clothing of a railway embankment with plants, the annuals, which at first take possession, have soon to yield to the perennials, and disappear after a year or two.

Fig. 211.—PART OF A VIRGIN FOREST IN NEW ZEALAND.

In New Zealand especially do we see this struggle for existence going on between native and introduced plants and animals. The Maoris have even recognised it in a proverb that "as the white man's rat has driven away the native rat, as the European fly drives away our own, and as the clover kills our fern, so will the Maori disappear before the white man himself." Perhaps the most remarkable instance is the threatened extermination by the common white clover of the New Zealand flax (*Phormium tenax*), a strong fibrous plant, with leaves sometimes ten feet long (Fig. 212); though when masses of the flax are broken up, other plants appear on the disturbed soil, yet the white clover reigns triumphant over all. The cattle, following the clover into the swamps, trample down the flax more and more, and so help its eradication—animal and vegetable thus working in harmony. The original vegetation of the colony is thus in places getting destroyed or deteriorated. A burr (*Xanthium spinosum*), introduced from Europe, clings to the sheeps' fleeces with such tenacity that it is almost impossible to detach it, and as it is consequently very difficult to dispose of wool so befouled, legislative enactments

have been passed against both it and the thistle. In like manner it has injured the pastures of Queensland to much the same extent as it does in Europe. Yet this plant, though now so generally distributed, is probably of Chilian origin.* It is the same in all countries, though more especially in those rich in species and where the soil is more valuable, until we come to the Arctic regions, where the species, like the natives, do not require to contend with other races—only with the elements. Some plants have, indeed, an actual antipathy to other species, being noxious to those which grow alongside of them. Thus the darnel grass and the fleabane are hurtful to wheat, the creeping thistle to oats, the purple spurge and field scabious to flax, the corn spurry to buckwheat, etc.†

Hence, when we speak of a plant or an annual being "rare" or "common," we unconsciously condense into these two words a wider world of fact and theory than is dreamt of. In a remarkable passage Darwin shows this, and there is richer food for thought in it than might even at first sight appear:—"When we look at the plants and bushes clothing an entangled bank," he writes, "we are apt to attribute their proportional numbers and kinds to what we call chance. But how false a view is this! Every one has heard that when an American forest is cut down, a very different vegetation springs up; but it has been observed that ancient Indian ruins in the Southern United States, which must formerly have been cleared of trees, now display the same beautiful diversity and proportion of kind as the surrounding virgin forests. What a struggle between the several kinds of trees must here have gone on during long centuries, each annually scattering its seeds by the thousand; what war between insect and insect—between insects, snails, and other animals—with birds and beasts of prey, all striving to increase, and all feeding on each other, or on the trees, their seeds and seedlings, or on the other plants which first clothed the ground, and thus checked the growth of the trees! Throw up a handful of feathers, and all must fall to the ground according to definite laws; but how simple is this problem where each shall fall, compared with that of the action and reaction of the innumerable plants and animals which have determined, in the course of centuries, the proportional numbers and kinds of trees now growing on the old Indian ruins" (p. 266).

This antagonism, indeed, as Sir William Grove has shown, is a most beneficent law, which prevails throughout all Nature. It is as indispensable to Ormuzd as to Ahriman, to the spirits of Good as to those of Evil. It is seen in the solar system and the stellar universe, each sun or planet of which is kept in its place and its orbit by antagonistic forces exerted upon it by other bodies, and its several paths are varied by the neighbourhood and pulling effect of them, so that, if the stars on one side of our solar system were removed, our sun and its attendant planets would rush off in the opposite direction. In the movement of the ethereal particles of light, in the internal struggles of the heart and arterial coatings of animals, in the fight for and against the forces at work in breathing, in the battle in the blood between the white corpuscles and the deadly bacteria—in brief, in every relation of social and material existence this antagonism is shown. War, according to Heraclitus, "is the father and king of all things."‡ Nor is it unfriendly to the race of organised beings. The rabbits on a barren hillside which have to labour hard for their living are healthy; those in the vale which luxuriate on rich grasses, which they obtain without toil, are often diseased.

Equilibrium of Species.—The equilibrium of species is thus preserved throughout the world, or in some particular locality, by the number of foes or allies they may have among the animals and plants inhabiting the same region. Thus a plant which dislikes sun-

* Shaw, *Journal Linnean Society* (Botany), Vol. XIV., p. 202.

† This subject is discussed in my "Manual of Botany—Anatomical and Physiological," p. 141.

‡ Or as Hobbes puts it, "War is the natural state of man." It is, at all events, the natural state of the rest of animated creation.

shine may prosper if there is a shade near, or another, which would be choked by the rank growth of its neighbour, may be preserved because its prickly leaves are unpalatable to cattle, which crop down its adversary. Again, a species will be protected by growing inside a thorny bush, while other individuals of the same species in the neighbourhood are nibbled by herbivorous mammals. Thus, in the New Forest in Hampshire (p. 209), the young oaks which are not rooted up by swine or consumed by deer are often indebted to the holly for their escape. Other instances are found in which a plant is defended against the enmity of some other subject of the vegetable kingdom by the numerous foes which prey upon the latter. Thus, scarcely any beast will touch the nettle, but fifty different species of insects feed on it. Again, Linnæus tells us that goats were turned into an island which abounded with a reed grass (*Agrostis arundinacea*), where they perished by famine, but horses which followed them grew fat on the same plant. The goat thrives on the water hemlock (*Cicuta virosa*), and meadow-sweet (*Spiræa Ulmaria*), plants which are injurious to cattle.* White sheep and pigs, it is notorious, are poisoned by certain plants which are harmless to dark-coloured individuals. The Virginia paint root (*Lachnanthes*), for example, causes the hogs of all but the black varieties of pigs to drop off.

Every plant has its own insects assigned to feed on it and keep it down, and these insects are again kept in check by parasites, which prey on them, and thus the fluctuating balance of life is preserved. Man also, by the changes which he makes on the surface of the soil, alters the proportion of species, though he makes up for this in other ways. He has disafforested many regions. For instance, St. Helena was once covered with woods, now five-sixths of this island are entirely barren. But the introduced species are so numerous that they have destroyed nearly all the indigenous ones; a circumstance which will be more fully noticed when we have occasion to consider the character of human influence on floras.

* "*Amœnitates Academicæ*," Vol. VI., p. 17, and Vol. VII., p. 409.

Fig. 212.—NEW ZEALAND FLAX (*Phormium tenax*).

A, Plant, seven feet high; B, Branch or Inflorescence with fruit, one-third natural size; C, Corolla or Flower, cut open, showing ovary, one-third natural size; D, Section of Fruit, showing imbricated seeds.

CHAPTER XVI.

The Agents Concerned in the Dispersal of Plants.

Structural Provisions for the Dissemination of Plants—Animal Agencies—Man—Instances illustrative of the manner in which he conveys Plants from one region to another—In Merchandise—By his Armies on the March—By Grain—By Species introduced into Gardens, etc.—Examples derived from the Cape of Good Hope and St. Helena—Birds—Examples of how they convey Seeds in their Stomach and by means of their Plumage—Mammals—Instances of their Services—Insects—Locust Flights—Inorganic Agencies—The Winds—Rivers—Currents—Vitality of Seeds in the Sea—Icebergs and Ice-fields—Hidden Stores of Seeds in the Soil—Examples of these—Alternation of Forest Growth—In America—In Europe—In Tasmania—In New Zealand—Orchids appearing Capriciously—Cause—Plants appearing when Fresh Soil is opened up—Railway Cuttings, etc.—Application of the Facts Mentioned—How far they Account for the Spread of Plants and to some Extent of Insects and Molluscs from one Region to Another—Conclusions.

It follows from what has been said in the preceding chapter that unless some means were provided for the dissemination of plants, they would soon perish in the struggle for existence. Only a certain number can possibly occupy a given space of ground, and thus the newcomers must necessarily seek other quarters. A single plant seeding every year would naturally scatter its seeds in an ever-broadening circle around it, or if it spread by roots much the same process would go on. But this mode of distribution would be slow, since infinitely more seeds would fall on to the ground than could be accommodated in the area required for the plants springing from them. But we know that plants spread from one country to another, and from one portion of it to another, with amazing rapidity. "They pass like night from land to land," advancing and retreating like armies; or they

Fig. 213.—TOUCH-ME-NOT (IMPATIENS NOLI-ME-TANGERE), A SPECIES OF BALSAM.

a, Flowering twig; *b*, *e*, Parts of the corolla (flower); *c*, Calyx; *d*, Pistil; *f*, Fruit bursting violently and discharging the seeds.

Fig. 214.—LIVERWORT (JUNGERMANIA BICUSPIDATA).

A, Fruiting plant, with *d*, unopened capsule; *B*, Fruiting plant, with *d*, opened capsule (sporangium); *C*, Spores; *D*, Elaters, with double spiral fibre which enables the attached spores to spring to a distance as well as to burst open the capsule during their uncoiling. *C* and *D* are magnified 300 diameters.

slip in one or two at a time until, as we have already learned, the old residents have to fight an unequal battle for existence with the vigorous immigrants.

Accordingly, the seeds of numerous species are provided with means whereby they can be rapidly disseminated, while in many fruits the capsule containing them bursts so violently as to enable its contents to be sent to a distance (Fig. 213). In the squirting cucumber (*Ecballium agreste*) the fruit forces out the seeds in the manner indicated by its popular name. In the sandbox tree—the "Javilla" of the Isthmus of Panama (*Hura crepitans*)—the valves open with such force that the noise has been likened to an explosion. We even see cryptogamic plants like the humble liverworts (Fig. 214) provided with springy elaters by which the spores are carried to a distance. Some seeds, like those of the firs and pines, have wings, others are furnished with hairs or pappi, like those of the dandelion, which enable them to be wafted by the wind. If this provision for flight helped even in a little way, a species thus furnished could in time make the circuit of any region in which its climatic limits might be found.

Animal Agencies.

There are, however, other agents at work in disseminating plants, which, when combined and acting as they have done through unnumbered ages, must exercise an important influence upon their modern distribution. These may be divided into Animal and Inorganic Agencies; and among the former, that of mankind must receive a prominent place.*

Man—though the agent most recently and in fewest numbers at work—has, perhaps more than any other, helped to carry the plants of one region to another, and to confound the original distribution of species. This has already been demonstrated in considering the struggle for existence (pp. 285 — 291). Wherever he goes he carries the seeds of plants with him — the merchant in the packing of his wares, the colonist with his household gods, and, more directly, among his cereals, while the march of his armies over the world might be traced by the plants which have sprung up in their tracks.

The most carefully cleaned grain will contain the seeds of the plants which have grown along with it, and which, like "ill weeds that spring apace," propagate rapidly until these "colonists" gain a footing, and in many cases, maintain it to the prejudice of the indigenous flora. The seaman conveys seeds in his ballast from distant lands—the climate of which is often similar to that of the region on which he shoots it to make room for his merchandise: accordingly every botanist knows that there are numerous foreign plants to be looked for in any locality where ships are in the habit of discharging their ballast. Since the extensive introduction of foreign wools, many plants of the wool-growing countries have sprung up in the vicinity of localities where this material is washed and bleached. De Candolle noticed this long ago in the vicinity of Montpellier, and mentions that in his time there was scarcely a year in which foreign plants were not to be found naturalised in a wool-drying ground (Port Juvenal) in the vicinity of that city. Among these naturalised plants are a knapweed (*Centaurea parviflora*), *Psoralea palæstina*, and *Hypericum crispum*, a species of St. John's Wort. Since that period various botanists have kept note of what plants successively sprang up, until now the list reaches the surprising number of 438—the species mostly belonging to the European coasts of the Mediterranean, whence most of the wool comes. However, representatives from Algeria, Morocco, Syria, Egypt, Asia Minor, and North and South America, have been found, including some new species, the native land of which is still unknown. Near Louviers, Bocquillon gathered out of Australian wool a quantity of the fruits of Leguminosæ (the bean and pea order),

* Some portions of this chapter and of the previous one appeared in papers by the writer in the *Geographical Magazine*, 1874; *La Nature*, 1875; and *Ocean Highways*, 1873.

which produce under his care numerous plants.* In the cleaning rooms of every woollen factory heaps of the fruits of plants may be seen lying, and as in some cases these are sold to the farmers as manure, numerous foreign weeds must spring up in their fields. However, though the seeds brought in wool to Montpellier give a varying character to the flora of the neighbourhood, yet only six species seem fairly naturalised and common. They are in brief "aliens" or "casuals." In the neighbourhood of Galashiels in Scotland, where there are extensive wool washing and drying works, more than forty species of plants have been picked up, most of which are new to Scotland, while some are strangers to Great Britain. †

Plants escape from gardens and get scattered far and wide. In Linnæus's day the fleabane or Canada thistle (*Erigeron canadensis*) had been seen scarcely a century in the Jardin des Plantes at Paris before it was carried by the winds over France, the British Islands, Italy, Sicily, Holland, and Germany.‡ The same observation might be made regarding various Chilian and North-West American species of monkey flower (*Mimulus*), especially *M. luteus*, which was introduced in 1825, and is now scattered over the British Islands from Cornwall to the Shetlands, and is getting equally at home on some parts of the Continent, where it is to all appearance wild, had the contrary not been known.

Similar instances could be multiplied to almost any extent, but the bearing of the foregoing is self-evident. Altogether, Mr. Watson considered that the denizens of Great Britain—plants which have been unwittingly introduced by man, and are now quite naturalised in a wild state—number sixty-four species, or about five per cent. of its total flora (p. 287).

When we consider how recently the flora of Europe has been carefully studied, we may imagine that many plants crept in from other regions without being remarked, and are now ranked as indigenous species. The same intermixture is going on in countries the flora of which is less perfectly known. In hot and ill-cultivated countries such naturalisations take place more easily. For instance, Wildenow mentions that *Chenopodium ambrosioides*, sown by Mr. Burchell on St. Helena, multiplied in four years to such an extent as to become one of the commonest weeds in the island. The feather-like seeds of *Asclepias carasavica*, introduced from Tahiti into New Caledonia as the stuffing of a bolster, have now multiplied that plant so fast as to cause serious uneasiness to agriculturists. In the same island the common couch-grass (*Triticum repens*), introduced a few years ago from Sydney, whence it came from Europe in the packing of some goods, has now sprung up in such abundance as to be rapidly killing the native grasses. The thorn-apple (*Datura Stramonium*), a plant of the East Indies and Abyssinia, had, more than a century ago, spread as a naturalised plant through every country in Europe, except Lapland and Norway, through the aid of gipsy quacks, who use the seed as anti-spasmodics or frequently employ them for more questionable purposes. The same plant is also widely scattered over the United States.

In like manner, through sheep and swine, various species of burrweed, particularly *Xanthium spinosum*, a native of Central Asia and Southern Europe, has spread within the last thirty or forty years as far north as the Baltic, and is now multiplying in North America, and, as we have seen (p. 289), in Australia also. More than fifty American plants have already naturalised themselves in Europe,§ though (p. 287) the compliment has been more than fully repaid by the number of Old World species which have crossed the Atlantic, and thriven far too vigorously in their new home, owing to the absence of their old enemies. European plants have even got naturalised in Greenland, among others, the

* "La Vie des Plantes," p. 269.

† Stuart, *Transactions of the Botanical Society of Edinburgh*, Vol. X., p. 170.

‡ *Amœnitates Academicæ*, Vol. II., p. 409.

§ Among the most recent is the beautiful "evening primrose" (*Œnothera biennis*), originally introduced in ballast, but now spreading all over Europe.

common tufted vetch (*Vicia Cracca*), in the old Icelandic "bygds" or settlements. In Europe it ranges from the Mediterranean to the Arctic Circle, and is found both in Central Asia and North America.

In the United States and Canada—British Columbia included—it is a finable offence to permit the fleabane to perfect its seeds, and in Ireland and Australia similar regulations are in force in regard to the eradication of the native thistles of those countries. In Denmark the same law prevails in reference to the corn marigold and common thistle; and in the early statutes of Scotland, whoever "poisoned the king's landes with weeds, thereby introducing a host of enemies," was denounced as a traitor.

The change from one locality to another is effected by a thousand circumstances. The herbs, which form so important a part of the domestic *materia medica* of the Eastern States of America, spring up along the prairie path just opened by the caravan of the settler. The herbarium of the botanist may accidentally sow seeds at the foot of the Himalayas, or on the plains that skirt the Alps. The straw and grass employed in packing the sculptures of Thorwaldsen were scattered in the courtyard of the Museum at Copenhagen, where they were deposited, and next year there sprang up no less than twenty-five species of plants belonging to the Roman Campagna.

A collection of the weeds of Upper Egypt, and the gardens of the Bosphorus, were found to be identical with those growing under the same conditions in New England;* and I have gathered in the neighbourhood of many of the least-visited seaports of Morocco numbers of the most common weeds of Northern Europe. Even along the caravan routes into the interior, and in the gardens of Fez, Mequinez, and the city of Morocco (Marak'sch), there are hosts of familiar vegetable colonists.

To such an extent has this gone on in certain countries, that the native vegetation has almost disappeared before the immigrants. Some plants, such as those which grow in wild places, by the banks of streams, or in rocky ground, will hold their own in spite of cultivation and even "high farming," which has a tendency to drain meadows and clean

Fig. 215.—THE EDELWEISS (GNAPHALIUM LEONTOPODIUM).

a, *a*, Plant; *b*, Blossom seen from below; *c*, Single outside floret; *d*, Inside floret [*c* and *d* enlarged].

out hedgerows, in which many species take refuge. Others, however, like wild animals and wild men, are unable to bear up against the malign influences to which they are opposed. In Britain there are so many hospitia for the persecuted wildings, that it is not probable that any of the native plants have been eradicated. Still some—like *Cypripedium Calceolus* (the lady's slipper), now found, and that rarely, only near Settle in Yorkshire, *Menziesia cærulea*, at present found only on the Sow of Athole in Perthshire, and *Lobelia urens*, now confined to a common near Axminster in Devonshire—are so nearly extinct, that, if not already exterminated, their end cannot be far off. In Middlesex it has been estimated that 58 out of 859 species of

* Marsh: "The Earth as modified by Human Action," p. 250; Schouw: "Earth, Plants, and Man," p. 115.

plants known to have inhabited the county, have been done to death by cultivation and building. Others are in danger from the hand of collectors, some ferns, like the woodsias and the forked spleenwort, being saved simply by the inaccessible places in which they grow. Already, even in Japan, some of the rarer plants of the once mysterious Fusi Yama mountain are growing scarcer, owing to the depredations of tourists, and in the Alps the Edelweiss (*Gnaphalium Leontopodium*) has been put under the protection of the Cantons (Fig. 215).

To such an extent has the introduction of stranger species, by man's instrumentality, gone on, that in certain countries—in the Cape of Good Hope and St. Helena, for example—there are more naturalised species than all the native ones put together. The latter bear much the same relation to the former that the human aborigines do to the European colonists. In the Cape the great grazing region known as the Midlands, formerly covered with shrubs and trees, has now got its vegetation entirely altered. According to the description given by Dr. Shaw, the sheep and cattle soon ate up the grass. They then attacked the greenwood, and destroyed so much of it that the rain supply was affected. Next the hardier plants of the Karroo plateau on the south-west began to travel northward, and compete in the struggle for existence with the feeble remnant of the Midlands vegetation, until what was originally a region covered by a characteristic vegetation is now merely an extension of the Karroo, the southern portion being entirely covered by *Chrysocoma truncifolia*, a plant belonging to that part of the colony, and, though at first shunned by the sheep,

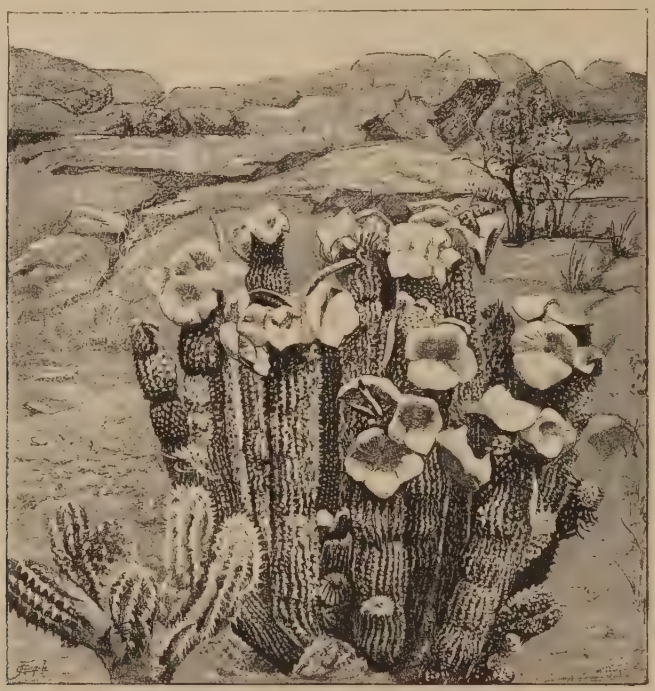


Fig. 216.—ADENIUM NAMAQUANUM (ELEPHANT'S TRUNK), A SUCCULENT PLANT OF SOUTH AFRICA.
(*From Fritsch.*)

now so readily eaten that their flesh tastes and smells of it. All this arid region is distinguished by succulent plants, euphorbias, stapelias (carrion flowers), mesembryanthemums (Hottentot's figs), adeniums (Fig. 216), etc.

St. Helena, at the time of its discovery in 1501, had a flora of about sixty species. This has increased to seventy hundred and fifty forms, though allowance must be made for the more minute search of later times. When first seen the island was covered with forests. Now fully five-sixths of it is barren, and the plants which are found on it are, with few exceptions, European, Cape, and American species, introduced with seeds, etc., the indigenous flora being almost entirely confined to a few patches on the slopes of Diana's Peak. The importation of goats, which soon increased to thousands, was the cause of the forest disappearing. In 1709 trees still abounded, and ebony was so plentiful that it was employed as fuel for the lime kilns. But by the first decade of the next century, timber was so scarce that the colony had to import coal. Even then there were so many remnants of the old forest that the trees might have reasserted themselves when the goats were killed off. However, the systematic naturalisation of foreign species made that impossible, for in the struggle for existence the natives had no chance with the immigrants.*

How armies help to scatter plants is shown by the fact that in the campaign of 1814 the Russian troops carried, in the stuffing of their saddles, seeds from the banks of the Dnieper and the Don to the valley of the Rhône, and even introduced the plants of the steppes into the environs of Paris. The Ottoman armies, in their European incursions, brought Eastern vegetables in their train, and left the seeds of Oriental plants to bloom on the ramparts of Buda and Vienna. Among these are *Euclidium syriacum*, which dates from the Turkish siege of Vienna, and *Crambe tartarica*, or "Tartar Bread," which is credited to a former inroad of these Asiatic hordes, just as Spanish plants along the line of the great Roman Wall in Northumberland and Durham are traced to the camps of that Iberian "Legio Victoriosa Sexta" who have stamped their name on so many bricks in the vicinity.

The hoary cress (*Lepidium draba*)—a plant of Central and Southern Europe and temperate Russian Asia—was introduced into England in 1809 by the returned troops from the disastrous Walcheren Expedition. Many of the troops disembarked at Ramsgate, and the straw of their mattresses was thrown into an old chalk-pit belonging to a Mr. Thompson, from whom the weed (now troublesome, and spread over many parts of the Isle of Thanet), Mr. Britten tells us, was long known to the country people as "Thompson's weed." In 1872 M. de Vibraye called attention to the fact that numerous plants, chiefly from Algeria and other parts of the Mediterranean coast, which had been used for forage by cavalry and artillery horses from beyond the sea employed in the Franco-German war, had sprung up on the fields occupied by the armies. These plants, though from warmer countries, were getting rapidly naturalised, and flourished vigorously even in the most barren spots. In the vicinity of Strasbourg M. Buchinger found, on examining bundles of hay served out to some cavalry horses in August, 1870, eighty-four species of plants belonging to Algeria. On examining the meadows in the following spring, two exotic *Centaureas* were discovered, and subsequent investigation showed that many more were continually springing up. Most imported species were found in the department of the Loire and Cher, and along the right bank of the Loiret, the old race-course of Blois, and other places occupied by troops. In March, 1872, young plants had sprung up near Blois and Orleans on barren sands where, from time immemorial, nothing had grown but a few stunted weeds. These amounted to over 160 species, most of them new to the locality. On the coast of Mekran the date-palm is common, but in the interior it is confined to certain lines of country, and the local tradition is that the palms along these routes in the interior sprang up from the stones dropped by the soldiers of

* Melliss: "St. Helena" (1875); Wallace: "Island Life" (1880), p. 281.

Alexander the Great on their return from India.* In Algeria the date-palm is thought to have been originally planted in the oases by the little Barbary monkey (p. 238), which feasts on it, though doubtless man has been quite as active an agent in the dissemination of this all-useful tree.

The rib-grass (*Plantago*) used to be known among the New England Indians as the "Englishman's foot," and in Oregon the sheep-sorrel (*Rumex Acetosella*) is to this day described as the "Hudson Bay Weed," the commercial company of that name being credited with its introduction in seed-wheat about the year 1840. It first appeared at Fort Nisqually on Puget Sound, but it has now spread far and near, crowding out everything else in the poor gravelly soil of the neighbouring prairie. The nettle is also a constant

Fig. 218.—THE "VINE LOUSE" (*Phylloxera vastatrix*), AN INSECT BELONGING TO THE ORDER HEMIPTERA AND ALLIED TO THE APHIS.

a, Perfect male insect; *b*, Wingless female; *c*, Eggs on a rootlet; *d*, Swellings caused by them; *e*, Swellings after the eggs are hatched. (*All much magnified.*)

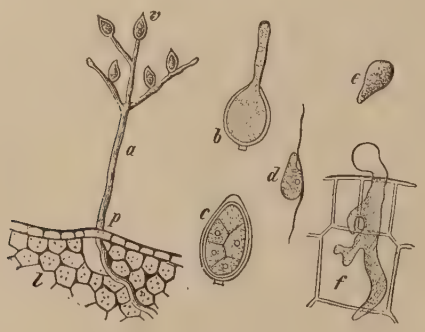


Fig. 217.—THE POTATO DISEASE FUNGUS (*Peronspora infestans*).

a, *p*, Fungus emerging from one of the stomata or breathing-pores on the surface of the potato leaf; *v*, Conidia, equivalent to seeds or spores; *b*, Conidium bursting; *c*, Conidium dividing into a number of nucleated zoospores; *d*, Free zoospore; *e*, Zoospore budding; *f*, Its thread or mycelium entering the leaf.

accompaniment of man in his migrations all over the world, the mere fact of a patch of it being found anywhere supplying the basis for a well-founded suspicion that a settlement of some duration had been on such a spot. A mere accident will determine the introduction of a species. The Canada thistle is said to have first sprung up in Europe from a seed dropped two hundred years ago from the stuffed skin of a bird. This is doubtful (p. 294), but, at all events, it is now one of the most common weeds. From the earliest date of man's roamings, this must have been progressing. For in the Swiss Lake Dwellings (p. 260) we find not only the Egyptian wheat (*Triticum turgidum*), and the six-rowed barley (*Hordeum hexastichon*), but *Silene cretica*, a weed of Southern Europe. It must, however, be remembered that man, if he assists in spreading species, also most materially aids in circumscribing the area of others by changes in the physical geography of a country, or by the introduction of species which retard the growth of either the indigenous or of other "colonist" species introduced by him. He takes with him the vine, but he conveys the fungus *Oidium* and the insect *Phylloxera* as well (Fig. 218). He plants the potato in a district, but plants the blight (Fig. 217) and the Colorado beetle at the same time. He has carried wheat to the New World, and with it the Hessian fly, which he has again (1886) conveyed across the Atlantic into the English fields.†

It must also not be forgotten that here, again, the struggle for existence intervenes. Hence we find that, while some weeds which are introduced into a country with everything

* Bartle Frere, *Proceedings of the Royal Geographical Society*, Vol. XVI., p. 22.

† In the Appendix to Pickering's work on the ethnology of Wilkes' United States Exploring Expedition, a list of the plants introduced into several countries is given.

to favour their dissemination in the shape of soil and climate fail to spread, others in no better case immediately make themselves at home. In America the corn-cockle extends rapidly, but poppies do not wander far afield; chickweed is as much naturalised as if it had been native, but groundsel is rare. The henbit (*Lamium amplexicaule*) spreads faster and becomes more plentiful than its near ally the purple deadnettle (*Lamium purpureum*); and, finally, Mr. Baker notes that, while viper's bugloss, couch-grass, and the creeping thistle, are so common in places as to be a nuisance, weed speedwells and coltsfoot, so frequent on barren clays in England, are rare, and field scabious (*Knautia arvensis*) is unknown as a naturalised weed. In these instances it will be found that there is something in the insect enemies or plant rivals which impedes the one or assists the other.

Birds.—Birds from their migratory habits and by quickly passing over great tracts of country help more than any other animals in disseminating the seeds of plants. They carry them in their plumage, in their stomachs, and even attached to their feet. Mr. Darwin had sent to him by Professor Newton a red-legged partridge (*Caccabis rufa*) which had been wounded and could not fly. Around the wounded leg a ball of earth had accumulated which weighed six and a half ounces. This earth had been kept for three years, yet when broken and placed under a bell glass, there sprang from it no less than 82 plants, comprising at least five different species. Out of six and three-quarter ounces of mud from the edge of a little pond 537 plants sprang, so that one need not be surprised to hear that in 1867 Darwin found in clay attached to the foot of a woodcock—a very migratory species—nine dry seeds, from one of which a plant of *Juncus bufonius* (the toad rush) grew, and as it is by no means uncommon to find in the earth clinging to the feet of birds pebbles as large as seeds, there is no physical difficulty in the latter being carried in this manner.

However, a more familiar mode by which birds convey seeds is by swallowing them, and then discharging them uninjured. That this often happens any one can satisfy himself by examining the crop of a wood pigeon between spring and autumn. Mr. Tegetmeier* tells us that the contents of one he dissected consisted of two whole acorns, five halves of acorns, 2,323 seeds or carpels of the common buttercup (*Ranunculus bulbosus* or *R. acris*), and 771 capsules of the common chickweed (*Stellaria media*), making a grand total of upwards of 8,000 seeds consumed in a single meal. Yet even that did not comprise the entire contents of the bird's stomach. Many undigested seeds pass through the alimentary canal of all animals (such as the horse), which are again swallowed by birds. Linnæus notices this vitality of undigested seeds when he calls attention to the fact of fields manured with new dung producing darnel or wild oats, though well tilled and sown with the best of wheat.† Graminivorous birds will often fly great distances before ejecting these seeds. It is, indeed, asserted that after a bird has swallowed a great quantity of seeds they do not pass into the gizzard for twelve or eighteen hours. Thus a flight of larks will fill the cleanest field with various plants, *e.g.*, nonsuch (*Medicago lupulina*) and others too heavy for the wind to scatter.‡ In like manner the blackbird and missel thrush when they devour ripe berries in too great quantities are known to consign them to the earth undigested in their excrement. Pulpy fruits—cherries, for example, the colours of which attract, and are developed only when the berries are ripe and therefore conspicuous — often serve for food while the stones are passed entire far from their place of growth, in a condition peculiarly fit for vegetation. Farmers in some parts of England feed turkeys with "haws" (the fruits of the hawthorn—*Crataegus Oxyacantha*) before sowing, to stimulate their vitality. In Ceylon, a species of thrush is of much assistance in scattering the cinnamon seeds over the island; and, according to Sebastiani, there are found on the Colosseum

* Natural History Section of *Field*, July 15th, 1871.

† *Amœnitates Academicæ*, Vol. II., p. 409.

‡ *Ibid.*, Vol. IV., Essay 75, § 8.

at Rome over 260 species of plants, the seeds of which must in the majority of instances have been carried thither by birds. Bartram, an early American botanist, affirmed that the common jay (*Corvus cristatus*) is "alone capable in a few years to replant all the cleared lands."

The American Poke-berry (*Phytolacca*), introduced into Bordeaux for the purpose of colouring wines, has been carried all over Southern France, Switzerland, and Tyrol, by winds. Rapacious birds help to scatter seeds indirectly by devouring the bodies of dead graminivora

Fig. 219.—FOREST IN THE CORAL ISLAND OF LUGUNOR, WITH COCOANUT PALMS, YOUNG PANDANUS, BARRINGTONAS, ETC. (*From Kittlitz.*)

and flying swiftly to great distances with them; or when tearing the bodies they assist in scattering the contents of the intestines. Seeds of oats, wheat, millet, canary, hemp, clover, and beet, experimented on by Darwin, germinated after having been from twelve to twenty-one hours in the stomach of different birds of prey, and two seeds of beet grew after having been thus retained for two days and fourteen hours — a space of time quite sufficient had the bird been flying to have carried the seed an immense distance. Audubon tells us that passenger pigeons (*Ectopistes migratorius*) were shot in the vicinity of New York with the rice in their crops which they must have obtained in the swamps of Georgia or of South Carolina. Now, as twelve hours are sufficient to digest the contents of their crops, these birds must have flown in six hours 300 to 400 miles. Every autumn millions of wood pigeons migrate from Norway to Scotland, and, doubtless, bring the seeds of Scandinavian plants to contribute to British field weeds. Birds fly to branches to devour berries and seeds at their leisure. In this manner the mistletoe is planted on the bark of trees by feathered raiders surprised before their meal is finished.

Again, birds of prey transport seeds in another way. Carcases of birds, when floating in the sea, often escape being devoured, and many kinds of seeds in the stomach of these individuals long retain their vitality. For instance, pea and vetches, which are soon destroyed by salt water, retained their vitality in the crop of a pigeon which had drifted on salt water for thirty days. If, now, this carcase had been swallowed by a bird of prey and carried to a distance, the seeds might have been transported very easily — these species flying with great swiftness. This is assisted by the habit which eagles and other "Raptores" have of conveying the bodies of animals to a distance to be devoured at their leisure. Fresh-water fishes also eat the seeds of many land and fresh-water plants, and these fishes are in their turn devoured by fishing-eagles, storks, and pelicans, which reject the seed in their droppings—many of these seeds, according to Darwin's experiments, being capable of germinating.

Migratory birds assist in carrying the seeds of one country to another often widely different in its flora. Every year certain birds cross the Atlantic to Europe, and *vice versâ;* others regularly proceed in the summer-time to the Arctic regions to breed, returning to more southern latitudes at the approach of winter, while others again leave Britain and other northern European countries for Africa and the Atlantic Islands. That these birds must occasionally carry seeds in the ways mentioned is highly probable. During their migration they fly very quickly, especially when helped by the wind. Indeed, this is absolutely necessary, for if they did not perform their journey swiftly, considering the immense stretch of ocean they must pass over without food or rest, they would inevitably perish. On the direct route between Scotland and Cape Farewell in Greenland snow-buntings (*Plectrophanes nivalis*) and other birds of passage continually alight on ships in spring and autumn, hundreds of miles from land. I have examined dozens of them, but never found anything in their stomachs except once, when among the half-digested contents of the gizzard of a snow-bunting appeared a seed of what appeared to be a *Suæda,* and on the plumage of the same bird was attached the achene of some plant, a buttercup perhaps.

In this way, it cannot fail for the flora of widely separated districts to be commingled, and some of the dissevered species of genera to be accounted for, without calling in the aid of any violent hypothesis to explain why some plant is found in a region where none of the other members of its genus or family are to be detected. There has, indeed, been a suggestion that the presence of the same plants in the Arctic and Antarctic regions may be accounted for by the wide range of the albatross (*Diomedea*) from the Kurile Islands across the Equator to Cape Horn;* and when we know that several species of albatross breed in the midst of dense low herbage, and have

* Grisebach: "Vegetation der Erde," Vol. II., p. 496.

often the burr-like flower heads of *Acæna** and other plants sticking to their plumage, the suggestion is not too wide of the mark. It has also been noticed that in oceanic islands (Vol. I., p. 31) a large number of the indigenous plants are those, the fruits or seeds of which could have been conveyed by birds (Figs. 219, 220).

Mammals. — Quadrupeds assist in some slight degree in disseminating seeds, which attach themselves to their hides. The startled deer or wapiti, when alarmed or chased, will often run for miles without stopping, and while dashing through thickets will frequently attach to its smoking flanks the hooked seeds of certain plants and carry them considerable distances. Many species have hooked seeds. For instance, Linnæus enumerated fifty genera which have such, and many more are known now; in England alone there are about thirty species so provided, not one over four feet high, and none of them aquatic. Yet, as Bentham has pointed out, the range of plants is not very much determined by the hooked or unhooked character of their seeds. The common burr-seeded forms of *Echinospermum* (borage) or *Cynoglossum* (Hound's tongue) are in no way more general or more rapid in their dispersion than the remarkably smooth-sided and equally common species of *Myosotis* (the forget-me-not genus), belonging to the same order. In Java there is a kind of civet cat which feeds greedily on the fruit of the coffee plant. After digesting the pulpy portion of the fruit, it ejects the two beans at what may be widely distant spots. According to Junghuhn, these coffee beans ejected by the civet cat are carefully sought for by the Javanese. Though mammals spread, yet they likewise circumscribe the range and help to keep up the equilibrium of plants, as Lyell showed as early as 1835.† The same author has pointed out that this is true of other animals. For instance, man, when he takes possession of a new country, soon drives away wild animals and migratory birds which would have helped to transport the seeds of plants. He accordingly takes their place in doing this, and "his intervention is strictly analogous to that of the species so extirpated."

Insects. — Although, as we have already seen (Vol. I., pp. 12–14), the range of many plants is dependent on the presence of certain insects, yet, as species actually concerned in disseminating them, the *rôle* played by insects is small. Still, it is not unimportant. In South Africa, for example, after the visit of a swarm of locusts, numbers of new plants have been observed to spring from their ejecta. Mr. Darwin notices that from seeds obtained from these pellets no less than seven individuals, belonging to two kinds of grasses, germinated. Now it is well known that locusts are markedly migratory insects, and within certain climatic limits pass rapidly over wide regions.

Inorganic Agencies.

The inorganic agencies—that is, those not considered in the previous section—which aid and have aided in the dissemination of plants may be regarded as the winds, rivers, currents, icebergs, and ice-fields. Some of these must always have been important influences on the distribution of species, while others have been acting for a limited period, and then never in a pre-eminently powerful manner. But, like those already discussed, they have, with the exception of man, been steadily engaged in this work from time immemorial, so that the aggregate of their results has been immense.

The Winds.—That the winds waft the seeds of plants hither and thither and assist in the spread of species, there is need of but little argument to convince any one in the slightest degree acquainted with the operations of Nature. That the breezes blow to indefinite distances the dust-like spores of Cryptogamia is self-evident, and to this may possibly be due the very wide distribution of the plants belonging to this group. The "dust" which issues when a ripe puff-ball is struck are these spores—so light, indeed, as to be almost beyond the influence of gravity.

* Moseley in Wallace's "Island Life," p. 250.

† "Principles of Geology" (3rd Ed.), Vol. III., pp. 36–38.

The seeds of flowering plants are not so easily scattered, though the tuft-like pappus or wing found on many species (such as dandelions and firs) must assist in their spread by currents of the air. Among the comparatively few plants known to him, Linnæus enumerates 138, mostly tall species exposed to the breeze, which had winged seeds; and when we consider that the same wind will prevail for weeks, with a force capable of transporting small seeds at the rate of fifty-six miles an hour, we cannot doubt that winds materially help in the dispersion of winged forms. Mr. Bentham* has, however, pointed out that this agency has been exaggerated. He thinks—and again it is just possible that he under-estimates it—that the pappi, wings, and elastic dehiscence of seeds and fruits, only suffice to convey seeds very short distances—not more, perhaps, than sufficient to place them immediately beyond the baneful influence of the parent's roots or shade—and can rarely be traced to have much influence on the general area of plants. In *Compositæ* (the sunflower and dandelion order) several species of *Eclipta, Elaphantopus, Anthemis, Lapsana,* etc., which have no pappus at all on their seeds, have a wider distribution than, for example, the great majority of Senecios (or groundsels), with light seeds furnished with a broad pappus. Furthermore, he points out that, if we observe thistle-down carried to some distance by high winds, it will generally be seen that it has left behind the seed to which it has been attached. Still, the influence of the wind is not to be minimised though, no doubt, only dust-like substances —like pollen, spores of cryptogamic plants, diatoms, etc.—can be distributed by it over wide stretches of land and sea in uninterrupted flights, and thus be brought into alpine regions. M. Kerner considers that the fruits and seeds of flowering plants which are provided with a web-like floating apparatus that distends itself in the form of a parachute are carried upwards by the ascending currents of air arising on sunny days in alpine regions on the cessation of the horizontal wind, but after sunset they sink again to the ground at a short distance; and the object attained by this floating apparatus is not so much the adaptation of the seeds for long journeys as to enable them to settle on the projections and in the crevices of steep precipices and rocks, and so clothe with vegetation those rocky walls which are not easily accessible by other seeds. The presence of membranous margins and wings favours the transport of fruits and seeds by horizontal currents of air. The horizontal distance, however, over which these seeds are carried scarcely ever extends farther than from one side of a valley to the other. Thus the distribution of the fruits and seeds of flowering plants, in so far as this is caused by the currents of air, can only proceed gradually. Fruits and seeds which are deficient in any kind of appendages that facilitate flight are scarcely influenced by currents of air; it is only when these seeds are of very minute size and extremely small weight that they can be driven short distances by horizontal winds.† In a tornado or a cyclone a fruit or seed might be borne a very considerable distance from the place of its production, and, in considering the inorganic agencies at work, this fact must not be lost sight of. In the steppes of Russia (Vol. I., p. 29) and of Africa (Fig. 221) a high wind will sometimes root up the bushes growing in the dry soil and sweep them before it for many miles, scattering the seeds as it whirls along. In this way plants soon spread.

Rivers.—These have not received that attention as disseminating agents which they deserve. Sweeping as they do through many degrees of latitude and longitude, from the interior of continents, through mountain ranges and varied climates, rising in high elevations, and debouching into the sea thousands of miles, it may be—like the Mississippi, the Amazon, the Obi, the Yenissei, or the Yang-tse-kiang—from their source, they must have an important influence in carrying the plants of one region to another. In this

* *Presidential Address to the Linnean Society*, 1869, p. lxix.; *Journal of the Linnean Society* (Botany), Vol. XII., p. 373.

† *Nature*, 1872, pp. 164–5.

manner, the plants of the interior of Germany will be tossed up on the shores of the Baltic, far from their native home, but yet in a region the climate of which does not prevent them

Fig. 220.—FOREST VIEW IN A LAGOON NEAR THE SEASHORE ON THE ISLAND OF UALAN, IN THE CAROLINE GROUP, SHOWING SONNERATIA, BALANOPTERIS, ETC. (*From Kittlitz.*)

or those of the Llanos of Venezuela, or of the foot-hills of the Andes on the plains of Brazil, from taking root, and maintaining the footing thus gained. Similarly, Alpine plants may

be brought down into the lowlands, and the plants of northern regions into countries far to the southward. In whatever direction a river flows, in that direction will seeds of

have shed them was found in any quantity. This happens at all seasons of the year. There has, for instance, been noticed growing not far from the mouth of the Columbia River

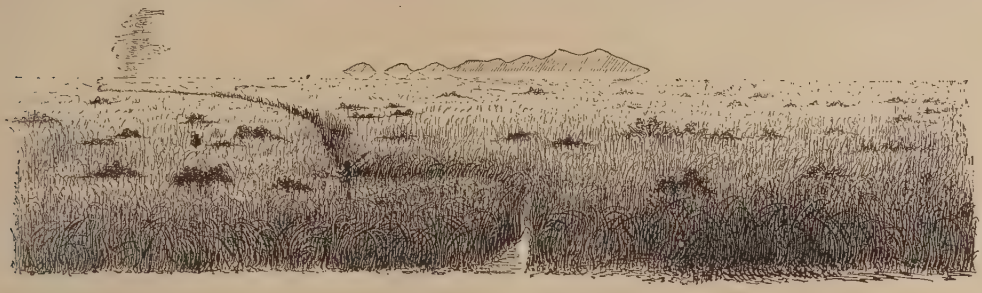


Fig. 221.—GRASS STEPPE IN EAST AFRICA, WITH "FATA MORGANA" AND WHIRLWIND.

plants be carried, and be tossed up here and there on its banks. The seeds of plants of the regions at the base of the Rocky Mountains, or of the widely different flora of the region between the Rocky and Cascade Mountains, will be carried down by the Fraser and the Columbia Rivers to the very shores of the Pacific; while those of the eastern slope of the same range, and of the great prairies, will be swept up on the shores of the Mississippi in Tennessee or Louisiana. All along the course of the rivers they will be tossed up on the banks, and grow or perish just as circumstances may determine. Sometimes they will spring up and die, the climate and soil not being suitable; but others will find a soil and climate propitious to their establishing themselves in a new home. No one who has ever, in autumn, leisurely sailed up some great river, flowing through a virgin country, and seen the river covered with the light seeds of the trees on its banks, or carrying down in its current the heavier ones of conifers, etc., throwing them up here and there in long lines on the moist low strand, or on the islands in the stream, but must have been convinced that rivers are important agencies in disseminating the plants of great continents. Every inland voyager must have seen the seeds of trees and other plants washed up on the banks of rivers hundreds of miles from where the species which could one or more individuals of *Pinus ponderosa*, a tree which is limited to the north, and for some distance south of the Columbia River, to the dry region east of the Cascade Mountains. There cannot be a doubt that it had been originally brought to the site where it was growing in the form of seeds, floated down by the river from beyond the Cascades. In like manner, rattlesnakes will be brought down by the spring floods, clinging to logs, but soon die in the moist woods which line the Columbia to the west of the Cascades. In spring and summer, these rivers, which take their rise in northern or alpine regions, suddenly rise to a great height from the melting of the snows at their sources; undermining the banks and carrying down great rafts of trees, uprooted, and encumbered with earth and stones; very often on sheets of ice, which prevent the earth from being washed off by the water. In this case, we cannot but believe that the seeds of many plants are carried down the course of the rivers, to be deposited in the rich alluvial mud of the river banks when, as generally happens, it just as rapidly subsides as it has swelled.

It may be argued that these floods, occurring chiefly in spring and early summer, when few plants are in seed, cannot accomplish much, however important otherwise they might be as agents of dissemination. In reply to this, we can only say that there are

vast numbers of *Liliaceæ* and other spring plants which are in seed before the floods occur, and that the dissemination of plants is accomplished by bulbs in the soil or even by roots, as well as by seed. The writer has seen a large raft of uprooted trees sweeping down a flooded American river, with numerous plants in flower on the upturned roots; and even on a quiet summer day he has passed, on his way up some of these rivers, the huge decayed trunk of a tree floating leisurely down stream with plants blooming on its decayed surface, these plants having taken root while the tree was lying rotting for years on the high bank of the river, before it had been compelled, by a land-slip, a freshet, or some other accident, to start on its long voyage. Weeks afterwards, on coming down the river, the same tree has been noticed left high and dry on the banks, with the same plants, still in flower or in seed, growing upon it. Could one doubt that these plants would establish themselves in this locality, though hundreds of miles from the place of their growth? In like manner, were further proof necessary, Sir William Dawson has pointed out that it has been observed in Nova Scotia that, when the wide flats of mud deposited by the Bay of Fundy are dyked in from the sea, they soon become covered with grasses and carices, the seeds of which are supposed to have been washed down by streams and mingled with the marine silt; fragments of grasses, it may be noted, also occur in the Pleistocene clays of the Ottawa.* How long seeds can retain their vitality in the soil has been long a disputed question (p. 310). However, for our purpose it is quite immaterial, for we do not require that the seeds be more than one season in the earth (and we know that they must be that and more in many cases before they can germinate) before being carried into the river on the roots of trees or on ice-rafts, as already described.

Seeds having been swept by rivers into the sea, they are mostly lost to the flora of the adjoining region, though in other cases they are carried by the currents to distances far from the mouth of the river, and may, by a conjunction of happy circumstances, be landed under conditions which will enable them to germinate and maintain a footing in the country which they have colonised.

Currents.—The currents of the ocean are the rivers of the sea, and just as the rivers disperse the plants of the interior of continents over these continents, so the currents disperse the seeds of plants from continent to continent. This, however, is in an infinitely smaller degree, on account of salt water sooner destroying the vitality of seeds than fresh water, and from the fact that the sea washes up these seeds in places less fitted for their growth than where rivers usually toss them. The great Gulf Stream, which flows from the Gulf of Mexico along the American coast, across the Atlantic, up the western shores of the British Islands, the coast of Norway, and at least as far East as Novaia Zemlia (Vol. I., p. 169),† where the warmth of the current is not altogether lost,‡ washes the seeds of tropical plants on the shores of Britain, and even on those of Iceland, Spitzbergen, and Novaia Zemlia. The huge bean of *Entada scandens*, a West Indian legume, has often been picked up on the west of Scotland, the Loffoden Isles, and the northern shores of Iceland, and it has been found on those of Spitzbergen, while on the low-lying Gulf Stream Islands similar discoveries have been made. The drift, however, of Siberia—great piles of trees, etc.—has been proved to be chiefly *Larix sibirica*, a species of larch, and, therefore, of Asiatic origin.§

The double cocoa-nut of the Seychelle Islands (*Lodoicea sechellarum*) was for long tossed up by the currents on the coast of Malabar and the Maldive Islands before its

* *Canadian Naturalist*, 1862, p. 100.

† This has of late years been controverted, with how much right we shall have occasion to inquire at a later date. Meanwhile, the points in dispute do not affect the facts stated.

‡ Petermann in Petermann's *Geograph. Mittheilungen*, 1865, pp. 150 *et seq.*, 1867, p. 184, 1870 (Heft. VI.. VII.), and "Papers on Eastern and Northern Extension of the Gulf Stream" (U.S. Hydrographic Office, 1871).

§ Agardh, Petermann's *Geographische Mittheilungen*, 1870, p. 196; Peschel, *Das Ausland*, 1870, p. 408.

real nature and locality of growth were known (Fig. 222).* Some seeds—like those of fennel (*Fœniculum officinale*)—are, from their boat-like shape, particularly well adapted for floating. These fennel seeds are carried by the sea in such quantities to the coast of Madeira as to have given a name to one of the best-known localities in that island—Funchal (or "Fenouil") Bay.

Fig. 222.—THE DOUBLE COCOA-NUT (*Lodoicea sechellarum*).

Similar facts might be cited with reference to the transporting power of other currents. We must, however, always remember that, though currents may transport fruits and seeds immense distances, their power is limited by the following facts. Firstly, they toss up seeds, etc., in most cases on shores where they can never grow, both on account of the nature of the soil and of the climate; secondly, that when they are tossed ashore they may be rotten or destroyed by the action of sea water, so that their vitality is gone.

Mr. Darwin and others have tried experiments with a view to testing this. Out of 87 seeds, 64 sprouted after an immersion of 28 days in salt water, and a few survived after an immersion of 137 days; and $\frac{1}{9}\frac{8}{4}$ plants with ripe fruit floated after being dried for above 28 days. An asparagus plant with ripe berries floated for 85 days, and the seeds afterwards germinated; and hazel-nuts, when dried, floated for 90 days and then germinated. We may conclude, therefore, that the seeds of $\frac{1}{1}\frac{5}{0}\frac{5}{0}$ plants of any country might be floated by sea currents during 28 days, and would retain their power of germination. So that, supposing that the average rate of a current is 33 miles (though some have nearly twice this swiftness), the seeds of $\frac{1}{1}\frac{5}{0}\frac{5}{0}$ plants belonging to one country might be floated 924 miles of sea to another country, and, when stranded or blown to a favourable spot by an inland gale, they would germinate.† Similar experiments have been made by Berkeley, Martins, Thurat, a Committee of the British Association, and the writer, with somewhat similar results.‡ Darwin found that the power of different orders to bear sea-water varied. *Leguminosæ* § resisted the salt water badly, as did the allied orders *Hydrophyllaceæ* and *Polemoniaceæ*. Seeds with hard husks will necessarily be less injured than others with soft porous ones. Hence cocoa-nuts are among the fruit-plants which spring up on a coral isle as soon as it raises its surface above the sea. Seeds can, however, be tightly jammed in interstices of the roots of trees and protected from the action of the water by stones, which block the entrance. Any one who has examined many upturned roots of great trees—especially if growing in gravelly soil—will know this. Out of one small portion of earth thus completely enclosed in an oak about fifty years old Mr. Darwin germinated three dicotyledonous plants. Accordingly, seeds in this condition can travel in the drift of currents to almost any distance without injury; and that they do so there can be but little doubt. Huge fir-trees from Oregon are frequently washed up on the shores of the Sandwich and other Pacific Islands, and that stones are often tightly fastened in about their roots—and, by inference, more rarely, seeds, insects, and land-shells—is proved by the fact that in former

* Teijsmann, "De Lodoicea sechellarum, Labill." (*Naturkundig Tijdschrift voor Nederlandsch. Indie*, etc., Deel XXXI., pp. 40–50).

† "Origin of Species," p. 429.

‡ Martins, *Transactions of the Botanical Society of Edinburgh*, Vol. VI., p. 279; Thurat, *Bibliothèque Universelle*, 1873.

§ Yet this is an order rich in cosmopolitan species.

times. before the introduction of iron into these islands, the stones so found were a royal perquisite, being of value in a coral island for making spear-heads, axes, knives, etc. (p. 23).

Every year the Siberian rivers pour into the Arctic Sea immense drifts of trees, which are tossed by the currents on to the coasts of Novaia Zemlia and Spitzbergen, or carried round Cape Farewell and stranded on the Greenland coast as far north as Disco Island, in about 70° N. latitude. That they occasionally bring in their roots seeds is probable, and finding a congenial climate on these Arctic shores, such seeds spring up. A log of mahogany has been stranded on Disco, being carried up Davis Strait by an in-draught from the Gulf Stream. In this way seeds of the temperate shores of the North-Eastern United States may have been conveyed to Greenland.

Could we prove that this has once happened it would be enough for our purpose; for we must recollect that we are dealing with eons, not with years, and that if this happened once in a thousand years it would amply suffice to commingle the Arctic (or other) floras in the course of the long period during which the climate and natural economy of the world have been in their present condition.

Islands very materially assist in the transportation of seeds by currents. For instance, a seed which could not bear travelling for a thousand miles might easily survive a voyage of three or four hundred miles. Accordingly, a current might carry it that distance to an island where it would spring, and its descendants, at some future time, drop and be carried or be blown into the same current which brought their ancestor, and be floated on anew to some other more distant island, and so on; the result being that a colony of the plant might be transported an indefinitely long distance by short stages, though it could not bear a long one. There is a strong suspicion that at least one plant has been brought to Europe by currents, viz., *Eriocaulon septangulare*, a native of North America, abundant in the lakes of Skye, Coll, and some of the neighbouring Hebrides, and Connemara on the west coast of Ireland, to all of which localities it might have been brought up by the Gulf Stream,* for, though the genus is a widely-spread one, these places are the only ones in Europe where it is found. Or possibly, since stray American birds reach British shores every year, it was brought by one of them. Sir Joseph Hooker enumerates no less than 144 plants of the Isthmus of Panama which were most likely carried by the currents to the Galapagos Islands, off the coast of South America, while most of those of the Keeling Islands (p. 22) might have been transported by this agent. In the latter group, and doubtless in many others, various species of land crabs materially assist in rescuing the seeds and fruits which, after

> "Drifting, drifting, drifting,
> On the shifting currents of the restless main"

have been stranded on their coral beach (p. 24).

That seeds can resist the action of sea water long enough to reach British shores from America, is proved by the fact that *Guilandina Bonduc*, a West Indian leguminous plant (one of those which resist sea water worst), was raised from seeds found on the west of Ireland, and that a bean of *Entada scandens* — the "West Indian Filberts" of the London street hawkers—(p. 306), after drifting 3,000 miles from the Antilles to the Azores, germinated at Kew. Now, taking the speed of an oceanic current at from thirty to sixty miles a day, it is clear that if a seed could survive immersion for ninety days—and several did do in the experiments mentioned—it is clear that a plant might, in this manner, be conveyed five or six thousand miles, and yet germinate in its new home.

Again, seed can be carried without detriment—from one congenial climate to another —through regions where the plants them-

* The West Indian seeds brought by the Gulf Stream could not, of course, grow in the British climate. But it is a grave error to affirm that this current could not bring those of America. As it passes along the American coast for a considerable distance, this is quite possible.

selves would perish. Seeds are, indeed, singularly tolerant of extremes of heat and cold. Spallanzani mentions some which absolutely germinated after being boiled, and Sir John Herschel affirms that the seeds of *Acacia lophanta* germinated more rapidly after being immersed for twelve hours in water of 140° than before, while Ludwig could not get the seeds of a species of cedar to grow at the Cape of Good Hope till they had been

Fig. 223.—FOREST GROWTH IN BONINSIMA, ONE OF THE BONIN ISLANDS, SHOWING CALLOPHYLLUM, HERNANDIA, TERMINALIA, ETC. (*From Kittlitz.*)

thoroughly boiled.* On the other hand, wheat left at the headquarters of the *Polaris* Arctic Expedition (Lat. 81° 37′ N.), where it must have endured frosts forty or fifty degrees below Zero, or even greater, germinated on being brought to England four years later.

Icebergs.—Icebergs and ice-fields have been a favourite theoretical method of accounting for the dispersal of certain plants. As is well known, icebergs (Vol. I., p. 375), on breaking off from the parent glacier, frequently carry a quantity of rock, earth, etc., which has fallen on it from the sides of the valley through which the glacier has reached the sea; and that this "moraine" is borne considerable distances by the icebergs cannot be denied. Ice-fields sometimes convey similar *débris* which has fallen on the ice attached to the shore during the undermining of the cliffs by frost and water in winter and early spring. No doubt this earth may, and often does, contain the seeds, bulbs, and roots of plants. I venture, however, after a familiar acquaintance with ice action, extending over many years, to doubt if this has much, if any, influence on the conveyance of plants from one region to another. In the first place, not nearly so much *débris* is carried on icebergs as is popularly supposed†; and then, after it has been carried off in this manner, it is soon immersed in a deep pool of water, formed by the melting of the summit of the iceberg, so that the seeds (if any be in the soil) run an imminent chance of being rotted. However, let us suppose that it is not so, and that the "seminiferous" moraine is carried southward (or in any other direction), on the surface of the wind- or current-propelled berg. But the ice raft has not gone far before it is lashed by the waves or melted at the base by warmer water, or by the wear and tear of its motion through the water; pieces will "calve" or break off, and before long the berg will capsize, owing to its being top-heavy, and the whole burden it bears be tumbled into the sea. In like manner, the ice-field will break in pieces, and discharge its load into an element uncongenial for the growth of plants.

The only possible chance a seed carried by ice has to germinate in a new situation is when the ice grounds on a low islet, or is dashed on a lee shore by the action of the winds—an event which rarely happens. Even when stranded on a low shore it cannot approach near enough for its burden to be thrown on land, as a low-lying coast has shallow water off it; or if deep off shore the cliffs are in general high, so that this amounts to the same thing. In either case, the chances are so out of all proportion to its seeds ever being discharged in situations favourable to colonisation, that though it would be rash to say that this has never occurred, yet, on the other hand, it seems like straining a point to class ice as one of the agents concerned in the dispersal of plants, or of animals, such as insects and molluscs.

Hidden Stores of Seeds in the Soil.—Before dismissing the agents concerned in the distribution of plants, it may be well to say a few words on this much-debated question. Alphonse de Candolle affirms that the soil of any country is a perfect store-house of seeds.‡ In support of that opinion it is pointed out that whenever a new piece of ground is turned up plants appear which were never before known in that locality. Some of the tales regarding the vitality of seeds must be received with considerable scepticism. We need not in this place revert to the more or less apocryphal reports of mummy wheat sprouting, as most of these tales have been proved to be gross frauds on credulous tourists, or to the seeds taken out of a tomb containing coins of the Emperor Hadrian, and believed to have been contemporary with the remains, having sprouted. These, and a host of similar stories, though not absolutely incredible, are, nevertheless, too much surrounded with doubtful circumstances for us to accept them with confidence, if they are to be received as the foundation on which to

* Appendix to Tuckey's "Voyage," No. V., p. 481, and Lyell's "Principles" (10th Ed.), Vol. II., p. 390.

† Some of the cuts which Prestwich ("Geology," Vol. II.,) has reproduced from Kane (particularly Figs. 71, 72, 73), are evidently not from nature, or have been "improved" by the engraver. They are simply impossible.

‡ "Géographie botanique," Vol. I., p. 625.

erect any theories regarding plant distribution.

There cannot, however, be much doubt that after the Great Fire of London in 1666, the yellow rocket (*Sisymbrium Irio*) sprang up on the dismantled walls of the city, though unknown there before, and no longer found in the immediate metropolitan district. We have seen (p. 300) that in the mud of ponds are many species of seeds. On the other hand, Mr. Bentham* was inclined to question this doctrine of stores of dormant seeds in the soil, and declared that we have no direct evidence that seeds can maintain their vitality for any great length of time, and, though he did not doubt but that seeds are in abundance at the bottom of ponds, he thinks that most probably these seeds are of recent deposition. Even then, this experienced observer is sceptical whether many, if any, of these seeds can remain an entire year without being devoured, stimulated into growth, or decaying.

How far this may be true of seeds in wet mud is a point on which a variety of opinions can be held. But that in drier situations seed will preserve its vitality for a long time scarcely admits of doubt. This is especially the case when it is preserved from direct contact with the air or the weather. On felling a large elm tree twelve feet in girth, Colonel Cormack of Shawborough, near Tewkesbury, states that he found in a cavity of the trunk a quantity of acorns, many of which germinated well, though from the edge of the cavity in which they were found (enclosed on every side) to the bark there was a distance of two feet two inches, this space showing 120 rings of wood.† Sir Thomas Dick Lauder found that the seeds of field weeds taken from the sand-covered barony of Cawbin near Elgin (Vol. I., p. 10), which got drifted over as early as the seventeenth century, had preserved their vitality, so that, if there is no error in either of these statements, they are sufficiently remarkable to warrant a careful revision of our ideas on the subject.‡

Alternation of forest growth, etc.—Closely connected with this subject is that which concerns the alternation of forest growth. It has, for example, long been known that in certain parts of North America oaks and other broad-leaved trees are taking the place of pines, while if a forest of oak or maple is cut down firs appear as the next growth. In Georgia, the Chinquapin (*Castanea pumila*) is rapidly disappearing, and whole tracts of Loblolly Bay (*Gordonia Lasianthus*) are observed to die out in two or three years, and the Red Oak (*Quercus rubra*) and Sassafras (*Sassafras officinale*) are showing similar symptoms of decay. In these cases something in the later conditions of the struggle for existence has been too much for the decaying trees.§ But the changes which happen after a forest fire has passed through the virgin woods are more to our purpose. A North American pine and spruce forest when destroyed by fire is succeeded first by a growth of brambles, which in time are replaced by dwarf birch, poplar, and bird cherry; then scrub oaks and various hard woods follow these, and pine rarely reappears except upon land long mellowed in the various operations of agriculture.

In the Southern Atlantic region much the same gradual change is going on in the composition of the pine forests under the influence of fire, though naturally the species are different. On the North Pacific coast there is, however, an exception to this rule. In Washington Territory, Oregon, and British Columbia, fir forests, when destroyed by fire, are quickly replaced by a vigorous growth of the same species. The redwoods destroyed are replaced by redwoods. But in the interior Pacific region forests destroyed by fire either do not reproduce themselves, or, when under "exceptionally favourable climatic conditions, a growth of trees recovers the burned surface,

* *Presidential Address to the Linnean Society*, 1869, p. lxxi.

† *Field Quarterly Magazine*, 1871, p. 318.

‡ In my "Manual of Botany," pp. 522–524, many instances of a similar vitality are recorded.

§ Jones, Silliman's *American Journal of Science*, 1846, p. 450; *teste* Johnston's *Agricultural Chemistry*, p. 549.

poplars and scrub pines replace the more valuable species of the original forest."*

In Europe we find much the same rule prevails, though this alternation of growth seems to have been going on in virtue of a law connected with the struggle for existence rather than from the causes indicated in the preceding paragraphs. Charlemagne hunted in the forest of Gérardmer in the Vosges, then composed of beech and oak, though the same wood is now mainly of various species of pines. On the Rhine, not far from Kaiserslautern, oak forests several centuries old are giving way to beech, while others of oak and beech are yielding to encroachments of pine. In the Palatinate the Scotch fir is succeeding the oak. In the Jura and Tyrol the beech and pine are seen to replace each other in many districts. When the time for a change of crop arrives the existing trees begin to languish one after another, their branches die, and finally their dry and naked tops are seen surrounded by the luxuriant foliage of their successor.† In Cæsar's day the Hercynian Forest (Harzwald) consisted chiefly of deciduous-leaved trees, but conifers now predominate. In Bohemia, Hochstetter tells us, pines alternate at long intervals with beeches. In Germany, it is very common to find in the peat-bogs in the fir forests a great number of oaks, and in Denmark we have seen (p. 262) that the present noble forests of beech ‡ were preceded by alders (*Alnus glutinosa*), these by Scotch firs (*Pinus sylvestris*), then again by oaks, and lastly by aspen (*Populus tremula*), which seems to have been the original tree which covered much of the country before the peat-bogs in which this chronicle is preserved were formed. In Styria, when certain sections of pine forest are cut down young oaks take their place.

In France, according to Dureau de la Malle, after the felling of timber in the forests of a particular district of that country, broom, foxglove, heath, birches, and aspen sprang up in place of the oaks, beeches, and ashes felled by the woodmen. Then after an interval of ninety years, or thereabouts, after the third coppicing, oaks and beeches reconquer their original position. This they retain for a long

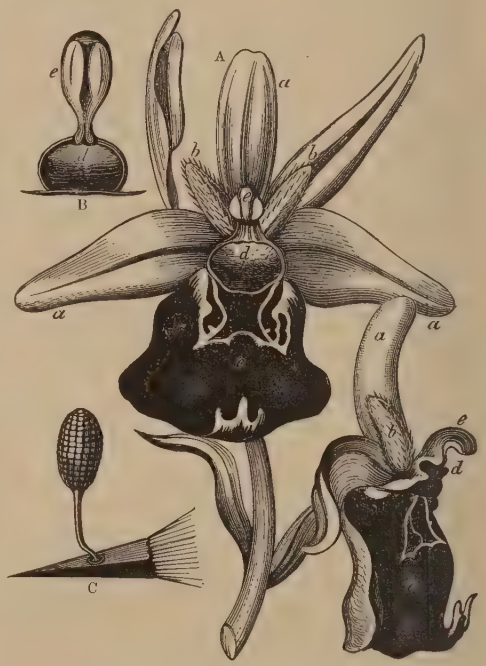


Fig. 224.—THE SPIDER ORCHID (*Ophrys arachnites*, Reich.).

A, Two flowers—the one in front view, the other in profile: *a a a*, The three outer divisions of the perianth; *b b b*, The three inner; *c*, The labellum or lip; *d*, The stigma; *e*, The Anther. B, Anther; (*e*), With two pollinia or pollen masses; underneath is the stigma (*d*); C, A pencil point on which is a single detached pollinium.

time, when the struggle begins afresh. This latter fact, Dr. Masters thinks, points to a connection with root excretions, to some poisonous matter being given off in the soil (p. 290), since mere exhaustion of the ground will not account for the phenomena in all cases, since a crop will fail in a particular soil after a time, though chemical analysis shows that the materials required by a given plant still exist in sufficient abundance within reach of its roots.

In Tasmania, wherever the virgin forest is cleared, there invariably comes up a thick

* Sargent in "Tenth Census of the United States," Vol. IX. (1884), p. 492.

† Masters, *Popular Science Review* (1873), p. 40; Hoffmann, *Gardeners' Chronicle* (1870), p. 664, etc.

‡ Vaupell: "De danske Skove" (1863), p. 28.

crop of a plant locally known as fireweed (a *Senecio*), which never grows except where fire has gone over the ground,* and in New Zealand the fiddle dock (*Rumex pulcher*) springs up on the formation of new streets, but soon becomes comparatively rare. It seems probable that it was one of the earliest plants naturalised in Auckland, but that it partially died out, its buried seeds retaining their vitality.†

Orchids appear capriciously in one place one year quite abundantly, while in the succeeding one they will be few in number, and so on. This is especially noted about the bee, fly, and spider orchids (Fig. 224), and it has been shown by Prillieux and others, that this is due to the fact that the flowering stage of the plant is arrived at one season, while another is occupied by the entire energies of the plant being devoted to forming the tubers and leaves. These plants, therefore, pass through several stages, which may be prolonged according to circumstances.

When fresh ground is opened, the appearance of plants new to the neighbourhood has

Fig. 225.—DOUBLE COCOA-NUT PALM (*Lodoicea sechellarum*) OF THE SEYCHELLES.

(*After a Sketch by Professor R. Hartmann.*)

* Wallace: "Island Life," p. 481.

† Kirk, *Transactions of the New Zealand Institute*, Vol. X., p. 367.

been noted (p. 310). This is markedly seen in a railway cutting. Species entirely new to the neighbourhood soon make their appearance, survive for a few years, and then disappear as the normal vegetation gains strength and permanence.* It is sometimes thought that these cases are apt instances of hidden stores of seed in the soil springing into life, when their vitality is stimulated by light and heat. In some cases, no doubt, this is so. But in the majority, the sudden appearance of the plant may be traced to wandering wind-blown or bird-borne seeds discovering a virgin surface of which to take possession, or to seeds that find the ashes of other plants favourable soils in which to make good their footing. There they may remain permanently, or in the struggle for existence with the more vigorous species temporarily displaced, they may succumb. But during their "squatting" they have seeded, and their seeds have been carried away, some to fall on stony ground, where they never germinate, or on soil already fully occupied, when the seedlings soon perish, or on a fresh surface like that of which their ancestors became seised in so informal a fashion.

When we look at these varied means of transport for plants we are apt to forget that, if these means are diverse, the obstacles to their thriving when transported are equally numerous. Bentham has pointed this out in a very lucid manner. He shows that the seed, on being deposited, must find a vacant spot, a soil to suit it, a degree of moisture and heat sufficient to stimulate it into growth before it is carried off or dies, and protection in its young and tender state after germination; it must, in short, survive its exposure to those enormous vicissitudes which will cause, for instance, an average of 99,999 out of every 100,000 seeds cast off by a foxglove (*Digitalis*) to perish before reaching the reproductive age. Clouds of small light seeds, carried by dry winds and deposited on an open soil suited for their growth, may, if this happens in a period of drought, be all devoured by birds or insects before a shower of rain shall enable them to fix themselves in the soil, while a single hard fruit swallowed and afterwards ejected by a bird in an accidentally vacant spot in moist, warm weather, or an acorn dropped by a rook on a ploughed field during the very short period that an acorn will germinate readily, may give rise to a young hawthorn or oak. The various means by which American plants have become introduced into Europe had been in operation for centuries before they succeeded in establishing the *Anacharis Alsinastrum* (p. 286), notwithstanding its great constitutional facilities, as evidenced by the extraordinary rapidity with which, since 1847, it spread into almost every district of Britain across theoretically impassable barriers.†

All this is indisputable. It is seldom possible for us to say in so many words that to the agencies described in this chapter the various phenomena connected, not with the origin of floras, but with their commingling, have been due. But when we remember the enormous quantity of seeds which many plants produce (p. 286), and the ease with which they can be carried to a distance, it is hard not to believe that they are often transported in the manner shown to be not only possible, but probable. It has, for example, been calculated that a wild poppy will, on an average, produce 6,000 seeds; a shepherd's-purse, 16,000; a chickweed, 3,000; a white goosefoot, 20,000; and so forth. Now, to use the words of Mr. Wallace—and, with the exception of Sir Joseph Hooker, there is no one better qualified to speak on the subject—supposing every year that a million seeds were wafted by the wind alone to the British Islands from the Continent, this would be only ten to the square mile. The observation of a lifetime would never detect one. Yet a hundredth part of this number would serve in a few centuries to stock Great Britain with a great variety of Continental plants.

* Wallace: "Island Life," p. 481, where many instances of this are given.

† *Presidential Address to the Linnean Society*, 1869, p. lxx.; On the means by which the fruits of grasses, etc., are distributed, Hildebrand, *Botanische Zeitung*, 1872. See also papers by Sir John Lubbock in *Fortnightly Review*, April, 1881, and by Mr. Worsley-Benison in *Journal of Microscopy*, July, 1888.

CHAPTER XVII.

The Distribution of Plants in Stations and Climatic Zones.

Cosmopolitan Plants—Species confined to Narrow Areas—Monotypes—Stations and Habitats of Plants—Sea or Salt Water—Salt Marshes—Fresh Water—Marshes and Fens—Prairies and Pastures—Cultivated Lands—Rocks, Gravel, and Loose Shingle—Rubbish Heaps and the Vicinity of Dwellings—Sands and Sterile Places—Forests—Shrubberies and Hedgerows—Mountains—Soil and Caverns—Local Peculiarities—Physiognomy of Vegetation—Horizontal Zones the Result of Climatic Conditions—Find their Equivalent in the Vertical Zones—Description of Meyen's Horizontal or Latitudinal Zones—Vertical or Altitudinal Zones—Influence of increased cold on the Flowering of Plants—Harvest Seasons of the World—A Lofty Mountain on the Equator exhibits from its Foot to its Summit a Précis of the Vegetation from the Equator to the Poles—Illustrations of this—Vertical Zones Different in Different Meridians, marked by different Species, though in General Characteristics the Same—Examples of these Derived from the Varying Elevation of Certain Trees on Mountains in Different Parts of Europe—The Beech—The Vine-Culture—Examples of the Plant Zones on Different Mountains—Chimborazo—The Alps—Etna—The Himalayas—Kilimanjaro—etc.

In the preceding chapters, we have seen that there are certain physical agents in the shape of soil and climate which limit the range of species, while on the other hand there are influences at work tending to carry species over the world, and transplant them wherever the conditions are favourable to their continued existence. In this way some plants have a wide range, and others, from causes not altogether easy to explain, an exceedingly circumscribed area.

Among cosmopolitan species, using the word in a somewhat loose way, since there are none quite worthy of being so designated, may be mentioned the ordinary bracken (*Pteris aquilina*), a fern which ranges from Lapland to the Amazon, the shepherd's purse (p. 287), the daisy, the common turf grass (*Poa annua*), the sow-thistle (*Sonchus oleraceus*), the nettle, the black nightshade (*Solanum nigrum*), and some of the forms already incidentally referred to (p. 271). On the other hand, there are groups which are confined to one, two, three, or a greater number of divisions of the globe.* Thus the Vochysiaceæ (an order to which the Copai-yé wood of Guiana belongs) are confined to tropical South America; the Chlænaceæ, a small order comprising a few species only, to Madagascar; the Epacridaceæ, heath-looking plants, entirely to Australia; the Stackhousiaceæ to the same island continent, with the exception of one species found in New Zealand and another in the Philippine Islands, etc.; while some genera, like *Ranunculus*, *Viola*, etc., are almost cosmopolites. But heaths, though not restricted to South Africa, are especially characteristic of that region, and *Mesembryanthemum* (Hottentot's fig genus), *Pelargonium*, *Borbonia*, etc., are chiefly or entirely represented in the same region; while not to enumerate many others, the remarkable genus *Welwitschia* (Figs. 206, 207) is confined to the sandy country of Mossamedes, on the plateau of Benguela, and to Damara Land, in South West Africa;† while the Calceolarias so common in our gardens are natives of South America, and even there confined either to the western side of the Andes, or to the southern extremity of the mainland and the adjacent islands. The nutmeg (*Myristica aromatica*), though cultivated in various tropical countries, does not grow wild out of Ceylon, nor is coffee indigenous to any country except a few parts of Africa, chiefly the south-west section of Abyssinia,‡ from whence it was introduced

* Hence called *monomic* (Greek, *monos*, one; *nomos*, region) *dinomic* (two regions), *trinomic* (three regions), *polynomic* (many regions), etc.

† J. D. Hooker, *Transactions of the Linnean Society*, Vol. XXIV., p. 1; Monteiro: "Angola and the River Congo," Vol. II., pp. 228–231.

‡ The word "coffee" is derived from "Caffa," one of the provinces of that country.

Fig. 226.—THE CEDARS OF LEBANON (*Abies Cedrus*) IN SYRIA.

(*From a Photograph.*)

into Yemen or Arabia Felix. *Lodoicea* (p. 306) grows only on Praslin and Curieuse, two small islets of the Seychelle group. The Norfolk Island Pine (*Araucaria excelsa*) is confined to the island of that name, the cedars of Lebanon (Fig. 226) to a few spots in Syria, and the Atlas Mountains in Northern Africa, and *Sequoia gigantea* (Fig. 194) is found only in a few localities in California, though, as we have seen (pp. 175, 176, 178, 204), these trees seem to be the straggling remnants of a once numerous and widely-scattered genus dating from Tertiary times. The redwood (*Sequoia sempervirens*) is also strictly limited to California, and even in that State to the northern coast-lying region underlaid by a particular geological formation (p. 284). The Wellingtonias, as the "big trees" are still commonly termed, attain an altitude of from 250 to 319 feet, and a diameter of from 19 to 36 feet, though some of the redwoods are not much, if anything, inferior to them in size, looking, grouped as they are in great forests, like perfect Titans compared with the lofty pines and other trees growing alongside of them —"seedlings of those that heavenward sprung, While yet the maiden moon was young."

Some species of plants are singularly local, *Origanum tournefortii* (a relative of the wild marjoram and the dittany of Crete) living on one rock alone in the small island of Amorgo in the Greek Archipelago. *Disa grandiflora*, one of the most beautiful of terrestrial orchids, is peculiar to the Table Mountain of the Cape of Good Hope, where it grows plentifully on the borders of streams and pools which are dry in summer, and *Cymbidium tabulare*, another orchid, is said to be confined to the same locality. The curious *Cynomorium coccineum*, a plant of the parasitic order, Balanophoraceæ, was at one time known as the "Fungus melitensis," and considered to be confined to the Hagiratal-general or Fungus rock off the islet of Gozo in the Maltese group. During the *régime* of the Knights it was so highly esteemed as a styptic in dysentery and for other purposes, that it was carefully stored and sent as a precious gift to friendly sovereigns and to the hospitals of the island. Indeed, up to a very recent date the salary of the keeper of the rock was a regular item in the Colonial accounts. Later researches have, however, proved that though the plant is extremely local, it is found not only in Malta and Gozo, but in the Levant, the Canaries, and Northern Africa, to which the flora of the island belongs. Again, the only species of *Nepenthes* or pitcher plant found in the Seychelles is confined to one elevated summit

Fig. 227.—SAMOYEDE TÛNDRA, NORTHERN RUSSIA, IN SUMMER.

of the group. Even in Great Britain—and other countries—there are often local species which in other regions are more widely distributed. For example, the yellow oxytrope (*Oxytropis campestris*), a common plant in Alpine and Arctic Europe, Russian Asia, and America, is confined to one spot among the Clova Mountains in Scotland; and *Cotoneaster vulgaris*, though scattered over Central, Southern, and Eastern Europe and Central Asia even to the Arctic Circle, is in the British Islands confined to the limestone cliffs of Great Orme's Head in Wales; while the Rock Potentil (*Potentilla rupestris*), a species which has a wide range in Central and Southern Europe and across the whole continent of Asia, extending as far north as Sweden, is in Britain limited to Craig Breiddin, a hill in Montgomeryshire.

The Mediterranean region is especially rich in these "monotypes," which may be regarded as probably the lingering remnants of earlier creations of plants, which, though now slowly dying off the earth, have been enabled by their superior vitality, their absence of enemies, or their power of adaptability, to face on better terms that struggle for existence in which their vanished contemporaries succumbed. Indeed, the area of many Mediterranean species has been gradually reduced even within historical periods, and still more at the date of the formation of the tufas of the south of France in an immediately preceding geological age.* We know that the power of adaptability in species differs very widely. Some are more, and some less, sensitive than others, to heat, cold, moisture, dryness, slight physical and chemical peculiarities of soils, and other circumstances, which render them unequal to the strain which an alteration in the physical geography of any area may demand of their constitution.

On the other hand, there are "social plants"—just as there are social animals—which live in great masses, often (like heaths, firs, grasses, etc.) covering extensive tracts of country, to the exclusion of nearly all other species. In addition to firs, pines, heaths, and grasses, mosses, lichens, in most countries, ferns in most places, birches in the north, crowberries in similar latitudes, and other plants, belong to this category. These social plants impart a monotony to the scenery of any region, such as the upland heathery moors, the tûndras of the North (Fig. 227), and the steppes and prairies of various regions. (Fig. 205, and Vol. I., Figs. 10, 13.)

* Planchon, *Natural History Review*, 1865, p. 202.

Stations and Habitats.

The various influences which we have described (pp. 273–285) determine the "habitats" and "stations" of a plant—in what kind of soil or position it shall live. There are conditions of soil and moisture which characterise the stations, while the habitats are essentially subordinate to temperature, to the degree of humidity, to transporting agents—in a word, to the influences which regulate or favour the dissemination and conservation of plants. The number of stations admitted by different botanists is sufficiently varied, according to the individual ideas of each author. Alphonse de Candolle considered the following as the best characterised:—

(1), *The sea or salt water*, in which grow marine plants, such as seaweeds, and among the flowering plants the *Zosteraceæ* (wrack or eel grasses), so plentiful along the shores of the brackish Baltic.

(2), *Salt marshes*, where flourish maritime, littoral, or saline plants, which require for their prosperity salt, and accordingly affect the vicinity of the sea or situations where "salt licks" are found, or where the soil is naturally impregnated with saline matter. Such plants are the Chenopodiaceæ or goosefoot order (*Sucæda*, *Salsola*—salt-wort—*Salicornia*—glass-wort—*Atriplex*—sea purslane—etc.), with fleshy or glaucous leaves; the sea-pink or thrift (*Armeria vulgaris*), found near the seashore, and strangely enough on the top of some of the European mountains,†

† This peculiarity the sea-pink shares with the scurvy grass (*Cochlearia officinalis*), and the sea plantain (*Plantago maritima*). But while on the sea shore they contain much soda and some iodine, on the mountains, potash is abundant and, according to the late Professor Dickie, iodine disappears. By some botanists the mountain thrift and plantain are regarded as distinct species.

the horned or sea-poppy (*Glaucium luteum*), etc. In warm countries there are trees (*Rhizophora*, or mangrove—Fig. 84—*Bruguiera*, another of the same family, *Avicennia*, or white mangrove) which prolong their roots into the earth under the sea and, by straining the silt and entangling the vegetation, form a sort of turf along the seashore.*

(3), *Fresh water*, which is sometimes inhabited by flowering plants; these are again divided into lacustrine species, proper to deep lakes, like the white and yellow water-lilies, the Anacharis (p. 286), and the frogbit (*Hydrocharis*), the water-soldier (*Stratiotes*), the lake sedge (*Scirpus lacustris*), the bladder-wort (*Utricularia*), and many species of pond weed (*Potamogeton*); plants of ditches and ponds (which class, however, pass insensibly into the preceding), like the flowering rush (*Butomus umbellatus*), the water-crowfoot (*Ranunculus aquatilis*), the water-veronica (*Veronica Anagallis*), etc.; plants of rivers, such as the blinks or water-chickweed (*Montia fontana*), and the brooklime (*Veronica Beccabunga*); and finally plants of inundated ground, which flourish chiefly during the winter and spring months, but remain in a parched condition during the summer.

(4), *The marshes and fens*, passing by insensible gradations into marshy prairies. These are distinguished into three substations: peat-loving species, which are social plants and possess long roots—such as the sundews (*Drosera*), cranberries (*Vaccinium Oxycoccos*), Marsh Potentil (*Potentilla Comarum*), etc.—and among cryptogams, especially the bog-moss (*Sphagnum*); plants frequenting grassy places with a spongy, very moist subsoil, formed often by an old peat moss, which yields to the foot passing over it, such as the butterwort (*Pinguicula*), the marsh marigold (*Caltha palustris*), the mealy primrose (*Primula farinosa*), etc.; and marsh plants properly so called—such as the bur-marigold (*Bidens cernua*), the rush-like *Scheuchzeria palustris*, etc.

(5), *Prairies and Pastures*, distinguished by social plants exclusively annual, which soon kill off any woody plants which have accidentally sprung up. The flora is varied, as the soil is loose or compact, the station near to the sea, in the interior, on mountains, etc. Most often in Great Britain the foundation is composed of grasses, intermingled with leguminous (pea-flowered) and composite (dandelion-like) plants, etc.

(6), *Cultivated Lands*.—This station supports an adventitious and floating vegetation, composed of such plants as man either has introduced (pp. 293–299), or are now, to a great extent, dependent on him for their growth. In the European fields various poppies (*Papaver Rhœas, P. dubium, P. Argemone*) are of this character; so are the corn-flower (*Centaurea Cyanus*), the charlock or wild mustard (*Brassica sinapestrum*), the corncockle (*Lychnis Githago*), etc. In reaped or ploughed land the sheep-sorrel (*Rumex Acetosella*), the viper's bugloss (*Echium vulgare*), etc., maintain a stubborn hold. In rice-fields some peculiar plants, like *Suffrenia filiformis*, are found; in flax-fields, *Silene rubella*, etc.; in vineyards, goosefoot (*Chenopodium*), *Fragus racemosus*, some species of rock-rose (*Helianthemum*), etc. However, the line between cultivated and adventitious plants is not always very distinctly marked or kept.

(7), *Rocks, gravel, and loose shingle* nourish plants to which the specific names *rupestris, saxatilis, petrosa, glareosa*, are attached. Some plants, like the pellitory, the wallflower (*Cheiranthus Cheiri*), the snap-dragon (*Antirrhinum majus*), the stone-crops (*Sedum*), the house-leek (*Sempervivum tectorum*),† etc., peculiarly affect walls and roofs of houses.

(8), *Rubbish heaps and the vicinity of dwellings* are the chosen stations of certain plants,

* These are sometimes called "Halophytes" (Greek, *hals* salt, and *phuton* a plant). In Eastern America the salt marshes are formed in much the same way by the eel grass (*Zostera*), as described by Professor Shaler in the *Report of the U. S. Geological Survey*, 1884–5, pp. 359–398.

† In Great Britain, however, as in the rest of Northern Europe, the house-leek is not an indigenous plant. It was introduced long ago from Central or Southern Europe, where it affects rocky situations in the great mountain ranges.

generally those fond of nitrogenous food—*e.g.*, nettles, docks, the celandine (*Chelidonium*), henbane (*Hyoscyamus niger*), etc.

Fig. 228.—THE BIRD'S NEST ORCHID (*Neottia nidus-avis*).

a, *b*, Full grown plant; *c*, Flower; *d*, Fruit.

(9, 10), *Sands* and *sterile places* form two stations, vague enough both in the character of the places and of the plants which frequent them.

(11), *Forests.*—These are, no doubt, distinguishing features in most countries, but the particular species characteristic of them are as varied as the trees and shrubs which enter into the composition of the woods. Many orchids grow in forests, clinging to the branches of trees in the way our humble bird's-nest orchid (*Neottia nidus-avis*) (Fig. 228) does, and other plants, like the beautiful *Linnæa borealis*, which the great Swedish naturalist permitted to be dedicated to himself, especially affect them.

(12), *Shrubberies and hedgerows* have plants which love these retreats, and where the botanist looks for them. These are chiefly climbers of some kind, like the Traveller's Joy or Old Man's Beard (*Clematis Vitalba*), which in July covers the hedges with its greenish-white blossoms, and, later in the year, merits its other popular name by the hoary appearance of the long feathery awns attached to its fruit; the black bryony (*Tamus communis*), the larger bindweed or convolvulus (*Convolvulus sepium*), so difficult to eradicate once it takes possession of a garden, etc.

(13), De Candolle considers *mountains* as a station; but mountains, in reality, unite within them many distinct and separate stations.

(14), Lastly, among well marked stations are the *soil* and *caverns* affected by subterranean species (p. 285) and *plants* which serve as stations for parasitic species, like the dodder, the tooth-wort, the broomrape (Fig. 229), the mistletoe, etc.—the range of which is, to a

Fig. 229.—THE RED BROOMRAPE (*Orobanche rubra*).

Parasitic on the roots of the wild thyme.

certain extent, dependent on that of their unwilling hosts.*

* Duchartre: "Eléments de Botanique," p. 1,024.

SAGO PALM PLANTATION IN AMBOYNA.

Local Peculiarities.

That every country has its own peculiar floras, and each species its own range, is a proposition so self-evident that it recommends itself to any one, no matter how superficial his observation. The vegetation of Italy is, for example, different from that of Great Britain, and the plants of California bear only a distant resemblance to those of Massachusetts, while in Australia and Britain there are scarcely two species in common, unless, indeed, they have been introduced within the past century (p. 271). Accordingly, numerous attempts have been made to map out the world into "botanical regions," characterised by peculiar groups of species, in contradistinction to the politically-limited territories usually taken as the area of "Floras," or works descriptive of the plants of a particular country. The "Flora of Hong Kong" is, for example, a well-known work. It describes the vegetation of the island of that name; yet this is not a natural botanical region, any more than is Great Britain by itself, though the books descriptive of its plants are numerous. These attempts will be considered in the course of the next chapter. It is only necessary to remark in this place that all such essays must be more or less unsatisfactory, since the best of such regions are, to a certain extent, artificially bounded. The physical regions of vegetation will be found, as Bentham remarks, to be often confused one with another in broken districts, vaguely limited when extending more uniformly over vast territories, and abruptly determined by impassable oceans and other barriers. "The floras of the Arctic and Mediterranean regions, of the White and Black Seas, are no doubt very different; but the change is so gradual, the journey from beyond Archangel to Yalta in this respect so monotonous, that it would be impossible to fix within a hundred miles or more the line where you have left the frozen North, or crossed the limits of the European, Siberian, and steppe regions, or entered that of the balmy South. So, again, the difference between the floras of Dalmatia and Portugal, or of King George's Sound and Moreton Bay in Australia, included respectively in the same regions, are surely greater than between those of Central Spain and of Central France, or of Timor and the opposite Australian

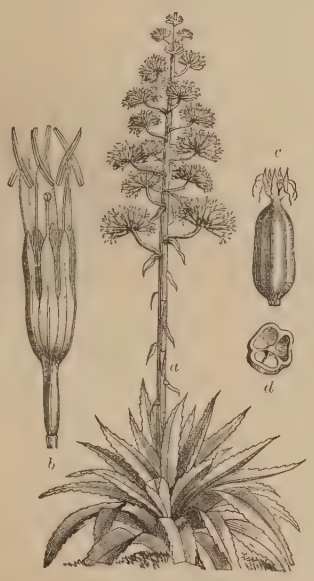


Fig. 230.—ALOE OR MAGUEY PLANT OF MEXICO (AGAVE AMERICANA).

a, The adult plant in flower; *b*, Flower; *c*, Fruit; *d*, Fruit cut across.

coast," which are separated by some phytogeographers into different regions.

When we study some well-defined order of plants, such as palms or magnolias or heaths, all the members of which require conditions very similar, we can produce more satisfactory results. However, when, in the various "botanical regions" so often mapped out, there exist many orders or parts of orders, each of which requires different physical conditions for its existence or prosperity, it naturally follows that it is impossible for all the members of these orders—or the orders themselves—to possess even tolerably equal limits of distribution. Hence occurs the difficulty of defining such regions.

The Physiognomy of Plants.—Even more captivating to the imagination is the grouping

of plants according to their physiognomy. There are, for example, the Coniferous or fir, pine, and cypress order, characteristic of Northern regions, the Agave or American aloe form (Fig. 230), characteristic chiefly of Camassia, and other forms, are its chief representatives; while in Europe and in Northern Africa (Morocco, for example) the various members of the Iris order, some of which are social plants, give a fitting display of it.

Fig. 231.—YOUNG DRAGON TREE (DRACÆNA DRACO, L.), IN THE PROTESTANT CEMETERY AT FUNCHAL, MADEIRA. (*After a water-colour sketch by Dr. Pechuel-Loesche*).

tropical or sub-tropical regions, and the Protea, Epacris, and Erica (heath) forms of Australia and the Cape of Good Hope. The Cactus form (Figs. 202, 203, 204, 234) is even more striking; while the Liliaceous form is represented by the lily, Amaryllis (Belladonna lily), and Iris (flag) orders. In Southern Africa, the Amaryllis, Ixia, and Gladiolus, with their sword-shaped leaves, represent this physiognomic type; in America, Alstrœmerias,

Among the most peculiar members of the liliaceæ are the dragon trees (*Dracæna Draco*) of the Canaries. This species has a tree-like form (Figs. 231, 232), divided or simple at the top, and often, when old, truncated, each trunk terminating in a head or tuft of lanceolate-glaucous green leaves. The resinous exudation found on the stem was long known as dragon's blood, and under that name formed, at one time, a considerable

export from the Canaries, though it is now very little used. The most famous specimen of this species was the colossal dragon tree of Orotava in Teneriffe, which was seventy feet high and forty-eight in circumference, and at the time when it was overturned by a storm (1869), was considered older than the latest built of the pyramids.*

Fig. 232.—THE COLOSSAL DRAGON TREE OF OROTAVA IN TENERIFFE. (*After an original sketch by J. Selleny.*)

The grass form is exhibited in the tree-like bamboos (Fig. 257), and in more northern regions by meadows, prairies, and pasture lands, or in the south by llanos and pampas, while the umbelliferous form, plants of the hemlock order or appearance, is exhibited in the flora of Kamschatka (Fig. 233). Here, in combination with the grass form, we find tall species of Heracleum (cow parsnip), one of which—*H. dulce*, most probably—is utilised by the natives for the extraction of a distilled spirit, and Angelicas, of gigantic proportions. These plants are seen more especially in the level districts on the western side of the peninsula traversed by the Bannaja Reka, a tributary of the Bolschaja Reka, where they are known by the Russian name of Medweshie Koren or Bear's Root. In the same region are found very tall nettles (*Urtica dioica*), the fibres of which were at one time —as they are still, or were until recently, on the western shores of Vancouver Island—used for making fishing lines and nets. These

* For the history of this tree, see Piazzi Smyth, in *Transactions of the Botanical Society of Edinburgh*, Vol. VI., pp. 250-261.

plants with birch forests give a peculiar character to the vegetation. In like manner, in the country on the other side of Behring Strait, in the neighbourhood of Sitka in Alaska, and southward to Oregon, the "Devil's walking stick" (*Echinopanax horridum*), with its long prickly stem and its palm-like crown of leaves, imparts at a distance either the

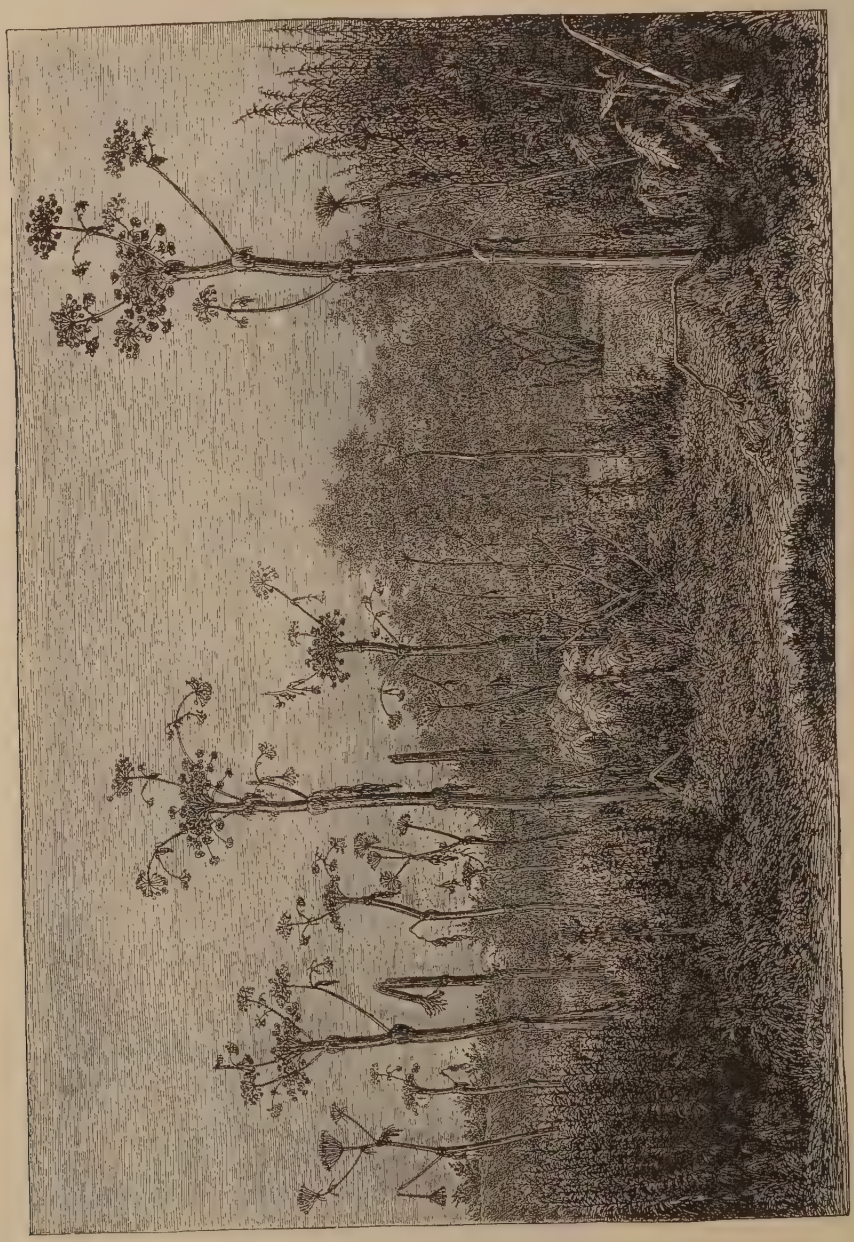


Fig. 233.—VEGETATION OF KAMSCHATKA.
With tall umbellifers and nettles in the foreground, and a birch forest in the distance. (*After Kittlitz*).

Fig. 231. VEGETATION AROUND CAIRO, EGYPT.

In the foreground are some huge Cacti or Prickly Pears (*Opuntia*), the height of which can be estimated by the figure of the Arab standing beside them; these plants are not natives, having been introduced from America; but in the background are several date-palms, and on the right are seen young trees of the same species.

(*From a Photograph.*)

umbelliferous or the palm form to the scenery, though it is actually an Araliaceous plant, a member of the same order as the Ginseng, so highly valued by the Chinese physicians. The palm form, which is usually associated with the bananas, plantains, cycads, and some plants (Figs. 201, 219, 220, 225, etc., and Plates of Sennaar Vegetation and Sago Palms in Amboina) is characteristic of the warmest region of the earth.

Then there are the mallow form, which includes the orders Malvaceæ, Sterculiaceæ, Tiliaceæ, and Byttneriaceæ—trees for the most part, of warm climates, with large leaves and conspicuous flowers; the mimosa form, represented by Leguminosæ with pinnate leaves, found in temperate and warm regions; the heath form, more especially characteristic of South Africa and of Australia, where it is "represented" by the Epacridaceæ and the Proteaceæ; the Casuarina (Fig. 210) form, leafless trees, with branches like the horse tails, found mainly in India, Australia, Tasmania, and the Pacific Islands; the Pothos form (Fig. 235), consisting of Arums, Caladiums, Callas, etc., some of which attain gigantic proportions; the fern form, so characteristic of the forest scenery of New Zealand and other countries; the willow form, found more particularly in northern countries; the myrtle form, of the Mediterranean Islands, Australia, various parts of the Andes, etc.; the laurel form, of South America; the dicotyledonous tree form, the oaks, beeches, elms, alders, birches, etc., of the North; the moss form, of cold regions; while the lichen form is characteristic of the Arctic and Antarctic Regions, in which (as on Deception Island) nothing exists except lichens, and then only in a small number of species and individuals.

These and a number of similar forms which might be given are, however, more or less fanciful. At the same time, any one who is familiar with the surface of different countries must have been struck with the physiognomy of vegetation, though it is likely enough these aspects have not presented themselves to every eye in quite the same way.

Representative Species.—The so-called "representative species" which impart similar physiognomic effects and play the same part in widely separated regions are more striking from a scientific point of view. Thus the heaths (Ericaceæ) of South Africa have their representatives in the nearly allied

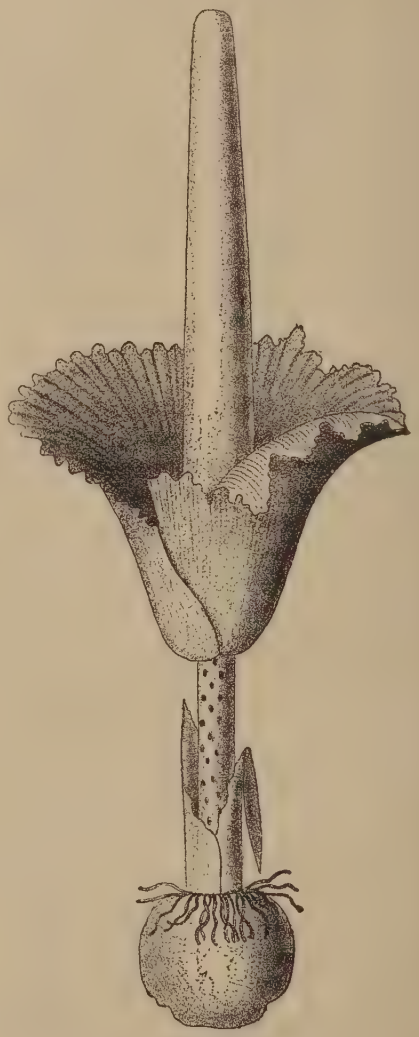


Fig. 235.—THE GIGANTIC ARAD OF SUMATRA (AMORPHOPHALLUS TITANUM, BECCARI).

With a flower over three feet in height, the spathe in which it is contained being more than six and a half feet in circumference; this plant, therefore, rivals the Rafflesias of the same region, the flower of one of which is often three feet across.

Epacrids of Australasia, while the cacti of the drier parts of America find their representatives in the succulent Mesembryanthemums and Euphorbias of Africa. The European Trientalis has its American representative in a nearly allied species, while the dog wood of America is represented by an allied species on this side of the Atlantic; and most species of Eastern American trees, especially conifers, find representatives on the Pacific side of the continent in forms different, though closely akin, which occupy similar soils, and possess physiognomic features of an identical character. Arctic and Antarctic plants, like many Arctic and Antarctic animals, have in like manner their representative species. Thus the crowberry (*Empetrum*) of the far North has a form nearly akin in the far South, while the butterwort (*Pinguicula*) of the Northern hemisphere finds in the Antarctic species its representative. The holly of the North is represented in the Mediterranean by *Ilex balearica*, the ivy by *Hedera canariensis*, the box by the *Buxus balearica*, and so on. Finally, not to multiply such instances, which are ample in number, we might point out that the Hydnoras of South Africa are representatives by the closely-allied *Hydnora americana* of the opposite continent. These forms may, in some instances, be due to the effects of climate, soil, and isolation, producing in course of time changes in the original species, some member of which had been carried far afield from the original home, while the unfitness of the intervening area for its growth explains its absence there, though in other cases a less simple solution of the problem is demanded.

Colours. — Some phyto-geographers have also traced a physiognomy in the colours of flowers, the white or pale-hued ones being more abundant in the northern regions than in the tropics, such colours also being more frequent in Alpine situations than in the plains. The xanthic or yellowish shades, Hinds considers, are the prevailing ones in the tropics during autumn, while the intense blues and violets are characteristic of the subtropical regions. Again in Oregon, Geyer noted many years ago that the lava-covered plains were characterised by vivid-coloured plants, while farther eastward blue and purple predominated, scarlet with golden yellow westward, glaucous green on the grassy prairies, and deep green in the valleys.

Horizontal Zones.

Though these physiognomic groups are more interesting to the artist and to the describer of scenery than to the physical geographer, their origin being due to causes not stretching very deep down in the arcana of Nature, no one can travel from north to south or *vice versâ*, without being convinced of the important part which climate plays in the distribution of plants, even when we do not claim for it all that the older school of botanists did. In passing from the Equator northward or southward we leave behind the vegetation characteristic of the tropics—the palms and bananas, and endless parasitic plants like orchids — and gradually approach regions characterised by species which we associate with more temperate lands until pine and fir forests make their appearance. Then trees entirely disappear, and dwarf creeping willows and birches are the only representatives of forests. Next, as the Polar regions are reached, woody plants vanish, and in time the climate gets too severe for even herbaceous species, and the vegetable kingdom is represented by a few lichens and mosses only. These familiar facts illustrate what we have already learned regarding the influence of temperature and other meteorological conditions on the range of species. Goethe has indeed indicated this alteration in the botanical aspects of a country in travelling from the Equator to the Poles, in the well-known lines in which he describes how—

> "In Rome upon Palm Sunday
> They bear new palms,
> The Cardinals bow reverently
> And sing old psalms.
> In other climes these psalms are sung
> Mid olive branches,
> The holly bough supplies their place
> Amid the avalanches.
> More northern climes must be content
> With the sad willow."

Again, when we climb a mountain we pass in a few hours through similar zones, every considerable elevation in altitude corresponding to several degrees in latitude, so that, while we have to pass over the 3,600 miles between the Equator and the Poles before we range from the region of palms and bananas to that of lichens and mosses, we can, by ascending Chimborazo, pass through similar zones in rising from the base of the mountain

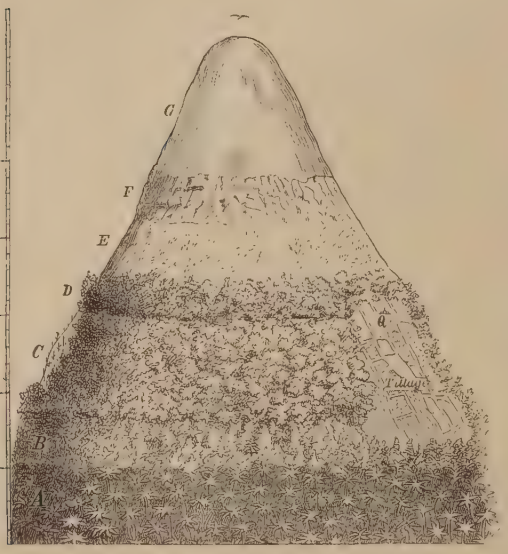


Fig. 236.—DIAGRAMMATIC VIEW OF CHIMBORAZO IN THE ANDES OF ECUADOR, ILLUSTRATING THE ZONES OF VEGETATION.

(*After Alexander von Humboldt.*)

A, Palms; *B*, Tree-ferns; *C*, Cinchonas; *D*, Befarias (ericaceous shrubs allied to rhododendrons); *E*, Grasses; *F*, Alpine plants; *G*, Snow region; *Q*, City of Quito (9,528 feet). A condor is shown flying over the summit of the mountain, which, according to various estimates, is from 20,517 to 20,703 feet high.

to its summit—less than 21,000 feet above the sea-level (Fig. 236).

An attempt has accordingly been made to mark off certain zones of vegetation * north and south of the Equator corresponding to the like zones in altitude. It must not, however, be supposed that though, for the sake of an approach to precision, these climatic zones are given within certain latitudes, they are quite so sharply cut off one from another; just as on the mountain sides, the zones graduate into one another, though, being of a depth so much less than the horizontal zones of the lower world are in breadth, this fact is not so readily noticed.

These horizontal or latitudinal zones are as follow:—

(1), The *Equatorial Region.*—This extends about 15° on each side of the Equator, and enjoys a mean annual temperature of from 78½° to 82½°. Its most characteristic forms are palms (Fig. 201), bananas and plantains, arborescent grasses like bamboos, screw-pines (*Pandanus*), gingers, orchids, the lianas or twining ropes so characteristic of tropical woods, and, to a smaller extent, cotton-trees (Bombaceæ), etc. (Figs. 219, etc.).

It corresponds with the region of palms and bananas in ascending a mountain within the tropics, extending from the sea-level to about 1,960 feet of altitude. The beauty and variety of forms, and their exuberance, freshness, and greenness, make this zone an extremely notable one.

(2), The *Tropical Zone* extends from the 15th degree on each side of the Equator to the tropics (lat. 23°), the mean temperature of the zone being 73½°—78¾°, with a summer temperature of 80½° to 86°, and a winter temperature of about 59°. The most characteristic forms are tree-ferns (Fig. 199), various species of the Convolvulus, Melastomas, and Pepperwort orders, beside other common tropical plants already enumerated. It corresponds to the altitudinal zone of tree-ferns and figs, extending from 1,960 to 3,900 feet (Fig. 220).

(3), The *Sub-tropical Zone* ranges from 23° to 34° of latitude, under a mean temperature of 62½° to 71½°, and a summer temperature of 73½° to 82½°. Tropical fruits, date-palms, doom-palms, palmettos or dwarf palms (Fig. 200), succulent Mesembryaceæ and Crassulaceæ (Hottentot fig and stonecrop orders), arborescent Euphorbiæ (Fig. 237), tea-plants (Fig. 242), aucubas, magnolias, etc., characterise it. The genus *Sempervivum* (houseleek) takes here arborescent forms, giving a strange character to the scenery; but the

* Meyen: "Outlines of the Geography of Plants" (Ray Society's Translation), pp. 161–223.

most peculiar plants are the tree-euphorbias or spurges, which, with their prismatic succulent stems, mimic in Africa (Fig. 237) the cacti of the New World. The milk of *Euphorbia balsamifera* is so innocuous and sweet that it is thickened to a jelly and eaten by the country people of the Canaries—a region remarkable for these arborescent spurges and similar plants*—while the sap of *Euphorbia canariensis* is as acrid as that of any other member of the genus. In the sub-tropical region south of the Equator we find Proteaceæ, Myrtaceæ, Epacridaceæ, Ericaceæ, Cactaceæ, etc., while in the Northern area palms and bananas grow in the plains. This horizontal zone corresponds with the altitudinal one of myrtles and laurels, which rises from 3,900 to 6,200 feet.

Fig. 237.—THE GIANT SPURGE (*Euphorbia grandidens*) OF SOUTH AFRICA, OVER THIRTY FEET IN HEIGHT.

(4), *The Warmer Temperate Zone.*—This embraces the space between 34° and 45° of latitude, including the southern part of Europe as far as the Pyrenees, and the south of France, Asia Minor, the tract between the Black Sea and the Caspian, and the north of China and Japan. Its mean temperature is from 53½° to 62½°; its summer temperature in North America, 77°; in Europe, 75¼° to 68°; in Eastern Asia, 82¼°; while its winter temperature is in America 44½° to 32½°; in Europe, 50° to 34¾°; and in Eastern Asia, 26½°.

In the Northern Hemisphere it is the region of evergreens, myrtles, laurels, oaks, olives, oranges, dwarf palms (*Chamærops*, Fig. 200), vines, cistuses, etc. In America oaks and Compositæ are its most marked vegetable features.

In the Southern Hemisphere part of the plants are evergreen, part only summer-green, or deciduous broad-leaved trees. This is the characteristic of the vegetation of New Zealand, Tasmania, Southern Australia, Chili, and Buenos Ayres. In some parts of this zone Solidagos (golden-rods), asters (Michaelmas

* Von Buch: "Physicalische Beschreibung der Canarischen Inseln," p. 115.

daisies), and Smilaceæ (climbing shrubs, to which the sarsaparilla of medicine belongs) abound; in other regions mimosas, myrtles, and Proteaceæ are common. The zone corresponds to the altitudinal one of evergreen dicotyledonous trees, which extends from 6,200 to 8,200 feet.*

(5), *The Colder Temperate Zone* includes a belt from 45° to 58°, with a mean temperature of 43° to 53½°, a minimum summer temperature of from 56¼° to 68°, and a minimum winter temperature in the interior of Europe of 14°.

Great Britain, the north of France, Germany, Denmark, and temperate mid-Europe, belong to this zone. In Asia, the Caucasus, a great part of the Ural Mountains, and the Altai and Daurian Chains, are comprised in it. It is continued to the Pacific, where there is a milder temperature, and consequently a more southern vegetation than in the corresponding latitudes on the western side of the continent. Much of North and South America also comes within it. In the Northern Hemisphere, broad-leaved trees, beeches, maples, limes, ashes, elms, and similar familiar trees, are of general occurrence, with firs, heaths, and moors covered with heather, or matted with creeping juniper. In America the species, though always different from those of Europe and most part of Asia, present a very similar appearance, and, in many cases, belong to the same genera as those described, maples, arbor-vitæ, yews, and tree-junipers, being frequent on both sides of the Continent, while on the Pacific slope the huge "cedars" (*Thuja gigantea*), the arbutus (*Arbutus menziesii*), and the broad-leaved maple (*Acer macrophyllum*) impart variety to the gloomy forests of fir and pine which cover so large an area of the western side of the Cascades and Sierra Nevadas. (Figs. 194, 226). In the Southern Hemisphere, evergreen dwarf trees, of sometimes the same genera as those in the North, with others strange to the opposite extremity of the continent, such as the Winter's Bark (*Drimys winteri*), with the usual bogs and moors, form its most characteristic features. Umbelliferæ and Cruciferæ are the orders best represented. This zone corresponds to the altitudinal one of deciduous, dicotyledonous, or broad-leaved trees, extending from 8,200 feet to 9,800 feet.

(6), *The Sub-Arctic Zone* is that belt which extends from 58° to the Arctic Circle in latitude 66° 32′. It has a mean temperature of 39¼° to 43°. The isothermal lines which run through it (*see* Plate) are, however, very irregular. Its summer temperature in America is 66½°, and in Europe and Asia 60¾° to 68°. The winter temperature of the former is 14°; of the latter (Western Europe), 24¾°, and of the interior of Russia 14° to 10½°. Firs, birches, and willows characterise it in its upper limits, while beeches, apples, cherries, and pears thrive on in Southern borders,† with nearly all our common kitchen vegetables. In the Antarctic regions the sub-arctic (or sub-antarctic) zone (as shown by the plants of South Shetland) presents a more polar character than it does in the North. This zone corresponds to the altitudinal region of Abietinæ (firs), which range from 9,800 feet to 12,500 feet above the sea.

(7), *The Arctic Zone* extends from the Arctic Circle to 72°, and possesses a mean temperature of from 28½° to 32°, though, towards the Eastern and continental portions, it is often for long periods subject to a cold as low as zero, or even below that grade. On its Southern lines (*see* Maps illustrating the Distribution of Plants), firs and other species still grow to a height which entitle them to be

* As a specimen of the difficulty experienced in characterising physiognomic regions, we may instance the fact that Schouw has named the flora of Southern Europe, together with that of part of Northern Africa, "the kingdom of Labiatæ and Caryophyllaceæ," from his belief that this region was characterised by a great number of species belonging to these orders. Mirbel, on the other hand, has promulgated an opinion the very opposite of the learned Dane's, in so far that he asserts that the Compositæ and Leguminosæ form the greatest part of the Mediterranean flora, namely, a fourth of the species—the Cruciferæ, Labiatæ, Caryophyllaceæ, and Umbelliferæ, being the orders next most numerous.

† In the Scandinavian Peninsula the apple and plum grow as far north as 63°·30, the cherry ceases to ripen in about 63°, while the pear fails at or near the parallel of 62°.

called trees, though their growth is stunted and their annual rings are thin and crowded together, and tillage is possible under favourable conditions. But on its Northern limits trees end, and broad areas present no more lofty representatives of their order than dwarf birches, creeping willows, the Alpine rose (*Rhododendron lapponicum*), the crowberry (*Empetrum*), the *Cassiope tetragona*, etc. None of them rise far above the ground; while over wide regions these dreary tracts, known in Russia and Siberia as tûndras (Fig. 227), and in North America as "barren grounds," prevail. In South Greenland—which, in spite of its Arctic character, is not in this zone—a few birches (*Betula glandulosa* and *B. intermedia*) appear in the sheltered valleys in the shape of shrubs, in rare cases, eighteen feet high, and in latitude 72° I have seen the stem of one creeping along the ground rather over two inches in diameter;* such cases are, however, very exceptional. The Arctic Zone corresponds with the altitudinal one of Rhododendrons, extending from 12,500 feet to 14,500 feet.

(8), *The Polar Zone* is the belt which extends from 72° to 82°. Its mean temperature is, at one point (Melville Island), calculated to be 1½°. In the extreme northern portion of Canada the mean temperature is 16½°, and the summer temperature 37½°, and in Asia and Europe it is 38¼°. The winter temperature is 28° in America, and 22¼° in Asia and Europe. Saxifrages, lichens, mosses, and other cryptogamia, are its most characteristic vegetation. No trees or bushes exist here, though, even in the highest points in this frozen land, the yellow Arctic poppy (*Papaver nudicaule*) may be found growing, during the long, bright, nightless, Arctic summer.† This zone corresponds with the altitudinal one of Alpine plants and lichens, which extend from the upper limit of shrubs to the snow line at 15,200 feet.

(9), Lastly, there is the *Circumpolar Region*, which comprises all the lands beyond 82°. Its mean temperature is so low that lichens and mosses comprise its principal vegetation; and in the Antarctic Regions—though no one has reached anywhere near its borders—even these must be lacking, since in islands much farther North vegetation of any kind is entirely wanting. In the upper reaches of Smith's Sound, in Grinnell and Grant's Lands, the flora of 80° to 83°—which is about the most Northern land yet reached in this quarter—proves that vegetation may be expected up to the Pole. The contrast between the vegetation of latitudes 80° to 83° in Grinnell Land, and Franz Joseph Land, in the same latitude, is striking in respect of the number and variety of plants. Here, to use Sir Joseph Hooker's words, "there is a sward covering a deep layer of vegetable matter exhibiting a brilliant assemblage of gay-coloured flowers, the resort of butterflies and bees" belonging to genera familiar to the English entomologist. But in Franz Joseph Land vegetation "exists only in rare and isolated patches." In other respects, it may be added, the Grinnell Land flora has all the usual Greenlandic characteristics, the number of monocotyledons to dicotyledons being twenty to forty-nine, which is pretty much that of the Polar flora generally.‡ This Circumpolar Region is equivalent to that of the snowy summit of high mountains, where cryptogams are the only plants, which on our typical mountain we may place at 16,400 feet.

That these climatic zones exist is self-evident, and that they are due to the influence of meteorological conditions is a truism which requires no argument to support. At the same time, we must repeat that it is impossible to always agree with Meyen in the limits which he has assigned to each, their limits, as in all botanical regions and zones, being more or less artificial. No plant ever ends abruptly at a specified latitude.

* Between 60° and 62° *Betula glandulosa* rises to a height of 3,000 feet above the sea, while *Betula nana* does not usually ascend higher than 1,000 feet, according to the data given by Lange in his *Conspectus Floræ Groenlandicæ* (1880), pp. 112—113.

† It was found at a height of 4,800 feet on Jensen's Nunatak, one of those isolated peaks in the middle of the inland ice of South Greenland, which have never been overwhelmed even during the Glacial Period.

‡ Nares: "Voyage to the Polar Seas," Vol. II., p. 307

It begins to disappear, and then vanishes; though under favourable circumstances, or in some more sheltered spot, individuals will always be found overstepping the limits which bound the range of the form at large. Dr. Meyen indeed admits that it is much easier to mark out these zones on paper than in nature. They are, nevertheless, useful for the localisation of facts, so long as they are not accepted too literally.

Vertical Zones.

The reader who has followed the statements in the preceding pages will have seen that the horizontal or latitudinal zones of plant-life as determined by climate find their equivalents in vertical or altitudinal zones, which are also limited by meteorological conditions. Only, while the distances north and south of the Equator are the limits in the one case, the necessary heat or cold is obtained in the other by the number of feet the zone is above the sea-level. This also affects the flowering of the plant. As we go Poleward the period of flowering and fruiting of a species is postponed in proportion to its distance from the Equator, and, necessarily, in a direct ratio to the less amount of heat which it obtains. Hence we know that, when the farmer in Kent has harvested his crop, his brother in Caithness has not begun to cut. There are, perhaps, only two months out of the twelve in which the grain harvest is not being actually gathered somewhere on the face of the earth. Thus, in the Southern Hemisphere, in the greater part of Chili, portions of the Argentine Republic, Australia, and New Zealand, January is the harvest month. In the Northern Hemisphere, it begins in February in the East Indies, creeping well into March as we come north. Mexico, Egypt, Persia, and Syria, reap in April; while Japan, China, Northern Asia Minor, Tunis, Algeria, Morocco, and Texas, do so in May, though, even in these regions, there are considerable differences between the northern and southern districts. California, Spain, Portugal, Italy, Sicily, Greece, and some of the southern departments of France, gather the harvest in June. July is the harvest month for the greater part of France, for Austria, Southern Russia, and the greater part of the United States of America; Germany reaps in August with England, Belgium, the Netherlands, part of Russia, Denmark, part of Canada, and the North-Eastern States of America; September is the time for Scotland, the greater part of Canada, Sweden, Norway, and the northern midlands of Russia; while the ingathering drags on slowly throughout October in the most northern parts of Russia and the Scandinavian peninsula. Hence, it would seem that November and December are the only months which have not a place in the harvest calendar of the world.

Thus the period of flowering and fruiting is postponed so many days for every degree of latitude. In like manner, according to the observations of the Schlangintweits,* the flowering of plants in the Alps is delayed fourteen days for every thousand feet, the climate getting about one degree colder for every three hundred feet of ascent; so that by climbing to the summit of Mount Etna (10,870 feet), we may "enjoy" the climate of Southern Greenland; while it has been estimated by Mr. Baker that the residents on the Surrey Hills live in an atmosphere not unlike that of the Northumberland coast.

A holiday tour from Norway to Italy or Spain, or even a sea voyage from England to the Azores, serves to impress these facts upon an intelligent traveller, even though his acquaintance with botany may be of the slightest. As we pass from north to south we leave behind the region of saxifrages, lichens, and snow, until, as we approach Drontheim, apples and pears begin to appear, and then oaks and fir trees. Still farther to the south—at Schönen and Sjeland—the beech makes its appearance. At Frankfurt-on-the-Main the lime and the elm are common, along with the chestnut, which, however, ends at the Pyrenees. Then come the hops, the clematis, and the ivy—temperate plants foreshadowing the climbers of the tropics—until, on the

* "Untersuchungen über die Physicalische Geographie der Alpen" (1850—1854).

other side of the Alps, the vine, bignonias, myrtles, arbutus, and pistachios, strike the eye, along with the dwarf palm and evergreen woods on the shores of the blue Mediterranean. And so on we proceed to the tropics of Africa, until we draw up under the shadow of the peak of Teneriffe in the Canary Islands, where there is a gigantic lily — *Dracæna Draco* (Fig. 232), the dragon tree — Callas, and tree-spurges (Fig. 237). Climb this, or any other high mountain under the same latitude, and we shall see that we leave the vineyards and the maize-fields in the plain below, and tramp through the forests of evergreen trees. At 4,000 feet we lose the plants which accompanied us. Then there is a small zone of deciduous trees, and we come to the resinous trunks of the Canary pine. Higher up we tear through low bushes until Alpine plants begin to appear, till finally the naked rocks set a limit to vegetation; and now, at 12,236 feet, there are no glaciers and eternal snow, because we are too near the tropics. Thus we have gone, in climbing this mountain, in a few hours through several zones of vegetation and fifty degrees of latitude, and journeyed from Spitzbergen to the Canary Islands.

In this graphic manner Schleiden has attempted to show the altitudinal or hypsometrical * range of plants as being akin to their horizontal or latitudinal distribution into zones. But it is the same all over the world, only the species are different in different regions. In general language, it may be said that the altitudinal range of plants is merely their range from south to north put into height, so that if we could tilt up that portion of the earth which lies between the tropics and either Pole into a gigantic mountain, the zones of vegetable life which we should have to pass through on our way north, we should then have to pass through in climbing this gigantic peak. Only, in reality, the zones on the mountain sides of the real world are much more abbreviated than they would be in our imaginary one—so that a few thousand miles are reduced to six times as many feet. In brief, the mountain would require to be "foreshortened." For instance, the beech, which in Europe extends to 60° north latitude, grows to the height of 3,000 feet on the Grimsel in the Alps; and the birch (*Betula alba*), which extends its range to 70° 40′ north latitude, does not appear on the mountain named till 6,400 feet have been reached. Each particular range of mountains, according to its latitude, is marked by particular trees or shrubs, marking the tree limit on them. For instance, in the Himalayas Quercus semicarpifolia, at 11,500 feet, marks the limit of the trees on the south side, though Betula alba, on the north, reaches as high as 14,000 feet. Coniferæ on the Pyrenees and Alps mark the upper limits of trees; Befarias (belonging to the heath order) indicate at 13,400 feet the upper limit of shrubs on the Andes; Rhododendrons, their near relatives, on the Alps at 7,500; while on the Himalayas Genista versicolor (an Asiatic relative of the Dyer's greenweed, and *Plante genêt*, the badge from which the Plantagenet kings took their name) ascends to 17,000 feet.

We have just mentioned the beech (*Fagus sylvatica*). In Great Britain it ascends to 600 feet above the sea; in the Riesengebirge it does not stop until it reaches 390 feet; in the Carpathians it halts at 3,600 feet; in the Western Alps 4,300 feet are its limit; in the Eastern Alps it rises to 4,920 feet; in the French Pyrenees (Canigou) its vertical bounds are at 5,250 feet; in the Middle Apennines 5,900 feet are its limit in the air; in the Southern Apennines 6,463 feet are the highest part at which it is found. On Etna (north and west sides) it rises to over 5,800 feet, while on the south and east sides, which are warmer, 7,080 feet are reached before it disappears. In Macedonia 4,920 feet constitute its vertical boundaries; while in the Pontic Mountains 5,900 feet are attained before it gives place to hardier species. In South Bavaria from 4,650 feet to 5,380 feet are about its upward limits. Towards the southern borders of its range it gets very sensible to heat. For instance, in Mont

* Greek, *hypsos*, altitude; *metron*, measure.

Ventoux it does not appear at less than a thousand feet; nor on the Cantabrian Mountains under 1,350 feet. On the Italian side of the Alps 2,900 feet are about its lowest range; in Istria it does not grow at a lower elevation than 1,500 feet; in European Turkey not under 900 feet; on the Middle Apennines not under 3,400 feet; while on Etna its lowest elevation is 4,035 feet.

Vine culture, again, can be carried on in Northern Hungary as high as 980 feet above the sea; on the Eastern Alps at 1,300 feet; on the Western Alps at 1,640 feet; on the southern side of the Alps at 2,460 feet; in France (Hautes Alpes) at over 3,900 feet; in Andalusia at nearly 5,000 feet; on Etna at 4,265 feet; and in Madeira at over 2,200 feet. Similar facts might be mentioned regarding the varying elevations to which other plants attain in different exposures and latitudes; but these examples may suffice to illustrate the principles enunciated.

The various vertical zones we have already noted when considering their horizontal equivalents (pp. 327–332). In the accompanying diagram (Fig. 238) the facts mentioned are presented in a more graphic form.*

In this diagram the mountain is presumed to be a typical one standing, like Chimborazo (Fig. 236), on the equatorial line. The zones, however, differ in different regions and latitudes, and even on different sides of the same mountain (p. 333), just, as we have seen (Vol. I., p. 360), as the elevation of the snow-line is different in different latitudes, or on different exposures.

Take, for example, the zone in which cultivation can be profitably carried on. On Mount Etna (p. 337) it ceases, unless in exceptional cases, at 3,300 feet. In Teneriffe it reaches to 3,000 feet in the region of vines (p. 333), embracing the zones of the Cactus and the Euphorbia. In Madeira it reaches 2,300 feet, when vines, temperate fruits, and corn cease, the region of true tropical plants having already ended at 700 feet. In the Carpathians 1,500 feet are its limit. In the Northern regions it is narrow, but in the tropics it is broad, extending to a high elevation. At a little under 6,000 feet there are banana plantations on Kilimanjaro, in Central Africa, though, did the climate suit the natives, the growth of temperate crops could be successfully followed at a much higher elevation. The potato (*Solanum tuberosum*), which is found wild in the forests of Bogota in New Grenada at 8,694 feet, has been cultivated in great perfection from time immemorial in the vicinity of the city of Quito in Ecuador, at an elevation of 9,528 feet.

The zone of woods extends in Etna to 6,200 feet. In the Canaries it rises to 4,080 feet, and in Madeira the chestnut does not cease till 2,950 feet have been passed. In Lapland, trees ascend in dwarf form to 800 feet, and in Finmark, in lat. 70° N., to about 750 feet while in a much lower latitude in Greenland there are no trees worthy of the name.

Shrubs rise in the Pyrenees and on Mont Blanc in the form of rhododendrons to 9,000 feet. In the Andes shrubby Compositæ ascend to 13,000 feet. In Lapland Betula alba (the birch), Vaccinium (blue berries), Salix (willows), reach 1,000 feet; while in Greenland similar plants ascend in places much higher.† Grasses reach a high latitude and a lofty elevation. In Melville Island (lat. 76° N.) the proportion of grasses is as 1 to 5, while in Britain it is 1 to 12½,‡ and in the South Shetland there are no flowering plants except grasses. In the Andes and on Kilimanjaro (p. 338) there is a grassy region at 13,000 to 14,500 feet, at which height—at Paramos, in the former range, for example—there are large *estancieros* or cattle farms. In the Himalayas grasses are found at 14,600 feet, and not unlikely extend higher still, while grain is grown at an elevation not much lower (p. 338); in the Swiss Alps the

* The numbers (1–9) refer to the number of the zones on pp. 328–331.

† *Vaccinium Vitis-Idæa* (the red whortleberry) rises to 600 feet; but the bog bilberry (*Vaccinium uliginosum*) disappears only at 2,300 feet; *Salix grænlandica*, the common willow of the country, has been found at 2,200 feet; while *Juniperus alpina* (the Alpine juniper) ascends to 1,920 feet over the sea.

‡ Robert Brown: "Chloris Melvilliana" (*Miscellaneous Botanical Works*, Vol. I., pp. 183–256).

common *Poa annua* flourishes at 7,500 feet. In the Andes, where the snow-line is on an average at 15,200 feet, corn will grow up to 10,000 feet. On the Caucasus (lat. 42° 30′ N.) the snow-line is 9,900 feet, while grasses prosper considerably over 6,000 feet. In the Alps (lat. 46° N.), when the snow-line is at 8,220 feet, corn grows up to 4,000 feet.

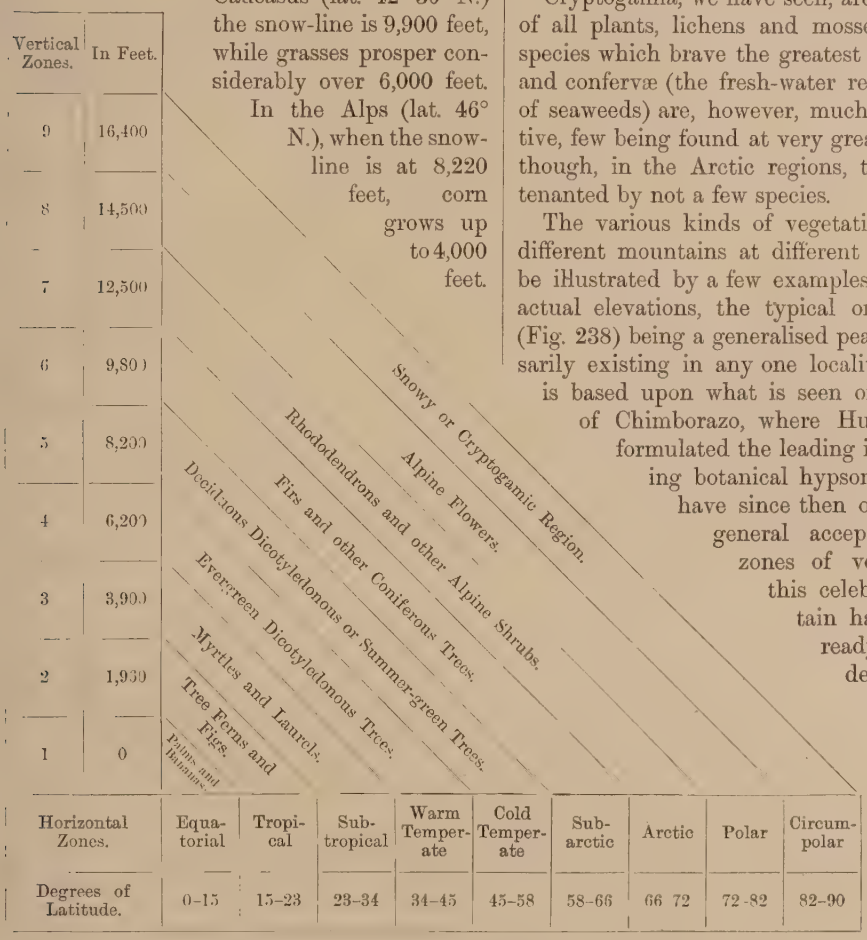


Fig. 238.—DIAGRAM ILLUSTRATING THE DISTRIBUTION OF PLANTS IN HORIZONTAL AND VERTICAL ZONES.

In Lapland—60°–70° N.—about 3,000 feet is the snow-line, though corn will not ripen at a higher elevation than 600 feet. In North Greenland and Spitzbergen the snow-line is in some severe years almost at the sea level; in other cases it will ascend to two or three thousand feet. But no corn can grow there. Potatoes are never larger than marbles, and the pods of peas will not fill. Radishes and lettuces are the only garden vegetables which approach perfection in lat. 70° N.

Cryptogamia, we have seen, are the hardiest of all plants, lichens and mosses being the species which brave the greatest cold. Fungi and confervæ (the fresh-water representatives of seaweeds) are, however, much more sensitive, few being found at very great elevations, though, in the Arctic regions, the pools are tenanted by not a few species.

The various kinds of vegetation found on different mountains at different heights may be illustrated by a few examples taken from actual elevations, the typical one described (Fig. 238) being a generalised peak, not necessarily existing in any one locality, though it is based upon what is seen on the slopes of Chimborazo, where Humboldt first formulated the leading ideas regarding botanical hypsometry, which have since then obtained very general acceptance. The zones of vegetation on this celebrated mountain have been already figured and described (Fig. 236). Again, in the Eastern (South Bavarian) Alps Sendtner has traced ten regions (Fig. 239). (1), The Lower Plain Region, or the region of the vine, from 880 feet to 1,300 feet. (2), The Upper Plain Region, or the region of the walnut, from 1,300 feet to 1,840 feet. (3), The Lower Mountain Region (oaks), from 1,840 feet to 2,700 feet. (4), The Upper Mountain Region (beeches), from 2,700 feet to 4,700 feet. (5), the Fore-Alps Region

(pines), from 4,700 feet to 5,800 feet. (6), The Lower Alpine Region (the mughus or creeping pine), from 5,800 feet to 6,660 feet. (7), The Upper Alpine Region (bushes, rhododendrons, and the Alp or upper pasture region generally), from 6,660 feet to 7,900 feet. (8), The Lower Snow Region (Alpine plants), from 7,900 feet to 8,860 feet. (9), The Upper Snow Region (limit of flowering plants), 8,860 feet to 9,500 feet. (10), The Region of Cryptogamia (mosses and lichens), from 9,500 feet upwards. This is the home of perpetual snow, and the elevation at which glaciers are generated. The heights given are, however, merely approximate, for (Fig. 239) the elevations to which the different plant-zones attain differ "according to local exposure to the sun and protection from cold winds, or the reverse," as John Ball puts it. Different sides of the same mountain also, as in the Eastern Alps, have their zones at different elevations.

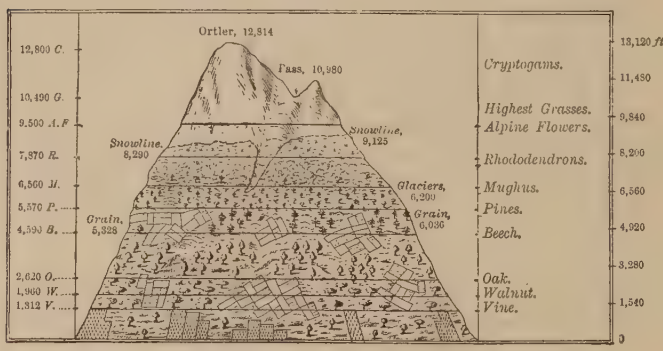


Fig. 239.—ZONES OF VEGETATION ON THE EASTERN ALPS.

In the Swiss Alps generally six regions can, according to Ball and Christ, be traced, though doubtless, by taking special peaks, a more minute sub-division of the zones could be justified. These are:—

(1), The Olive Region, though in the plains—such as that of Upper Italy, which in winter is colder than Great Britain—the olive only grows in sheltered places at the foot of the mountains and by the shores of the Italian lakes. By Lake Garda we find evergreen oaks, and lemons in abundance, though the latter require protection during the winter.

(2), The Vine Region, which rises to 1,800 feet on the northern slopes, and to 2,300 feet on the western and southern sides. Though the vine is more tolerant of cold than the olive, it is only in the deeper valleys of the Alps, with good exposures on sunny slopes, that the necessary conditions for its growth are found, since a mean summer temperature of at least 68° is required for the production of tolerable wine.

(3), The Region of Deciduous Trees. In Northern Switzerland the beech rises to 4,300 feet, while in Southern Switzerland there are woods of chestnuts as high as 3,000 feet. Here also we find corn-fields, oaks, ashes, and sycamores, though many of the ancient woods have been exterminated, or replaced by pine and Scotch fir, which do not suffer so much from the ravages of goats. Timber, on the northern slopes, is usually found as high as 4,000 feet, and on the southern side it attains an elevation of one thousand or even fifteen hundred feet more.

(4), The Region of Conifers is sometimes known as the sub-Alpine region. In North Switzerland the pine rises to 5,900 feet, the larch, spruce, and silver fir in the Central Alps to 6,900 feet, and in the Ticino Alps to 5,900 feet. This is the great pastoral region of the Upper Alps, where, for half the year, the flocks feed, hay is cut, and general dairy operations are carried on. Here are many of the Alpine villages, some of them standing as high as 6,000 feet above the sea.

(5), The Alpine Region includes the space between the upper limit of trees and the region of perpetual snow, which in the Northern Alps may be put at 8,860 feet, in the Southern Central Alps at 9,850 feet, though on the Jungfrau, lichens, the Ranunculus glacialis, and in Piz a Soldanella, are found much higher. This Alpine Region, with its three rhododendrons, clumps of red or pink flowers, its bush junipers, its bilberries,

and dwarf willows, is one of the most picturesque of all the mountain zones.

(6), The Region of Glaciers and Perpetual Snow.

In the Plate of Alpine Plants of the Limestone Alps given in Vol. I. some of the most characteristic of the Swiss mountain species are figured. Among them are, in the foreground, a violet, the *Aster alpinus*, the *Dryas octopetala*, the *Saxifraga Aizoon*, etc. *Gentiana acaulis*, *Primula Auricula*, *Silene acaulis*, and other forms, also appear. In the background is the famous Edelweiss (*Gnaphalium Leontopodium*) and one of the Alpine roses (*Rhododendron ferrugineum*), while in an overhanging precipice is the mughus, Krummholz, or creeping pine (*Pinus Pumilio*), so common in the Eastern Alps that, as we have seen, it often forms a distinct zone above the level of the other species of the genus to which it belongs. Again, when we pass southward to Etna we find a somewhat different arrangement of the climatic zones of vegetation (Fig. 240).*

(1), There is the Cultivated Region—the "regione coltivata" or "Piedmontana" of the Sicilians—which terminates approximately at 3,500 feet above the sea, though on the route to the summit, Nicolosi (2,889 feet) is about its limit. In this region the vine (which sometimes reaches over 4,000 feet), the date-palm (up to 1,700 feet, though it does not always ripen its fruit), corn, pistachio nuts, mulberries, oranges, lemons, figs, and other fruit trees, olives (to 2,300 feet), aloes, various species of cactus or prickly-pear, etc., grow luxuriantly in the rich volcanic soil.

(2), The Woody or Forest Region — the "regione boscosa," or "selvosa"—begins at the upper termination of the cultivated zone, and extends in a belt of varying breadth to the height of about 6,560 feet. This is the region of oak, beech, pine, birches (*Betula alba* and *B. ætnensis*), poplars, chestnuts, ilex, and cork trees, though these species attain to very different heights on the mountain side. A pine (*Pinus Laricio*) rises to the height of 6,430 feet; the great chestnuts —the celebrated Castagno di Cento Cavalli— are found in the forest of Carpinetto, on the east side of the mountain. The rye grows to the height of 5,850 feet, and a shrubby, broom-like plant (*Gonocytisus ætnensis*) is, next to the pine mentioned, the hardiest of the species found in this region. In this pleasant zone numerous flocks pasture during the spring and summer.

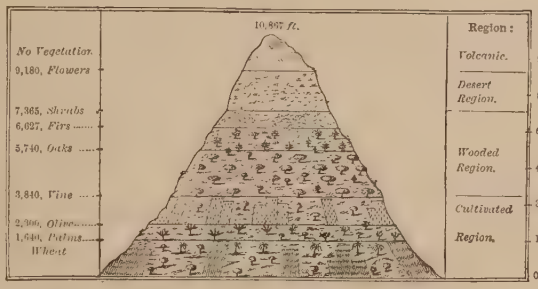


Fig. 240.—ZONES OF VEGETATION ON MOUNT ETNA.

(3), The Desert Region — the "regione deserta"—is the belt comprised between 6,560 feet and 9,330 feet. It is the zone covered with the ejecta of the volcano, and nourishes very few plants. The shrubs found terminate at 7,360 feet, in the shape of junipers (*Juniperus hemisphæricus*) and barberries (*Berberis ætnensis*), while flowers ascend somewhat higher. *Astragalus siculus* (in tufts three or four feet in diameter) ranges between 7,360 feet and 8,700 feet, though we find all over the zone such characteristic species as violets (*Viola gracilis*), *Saponaria depressa* (a soapwort), *Senecio ætnensis* (a groundsel), *Rumex ætnensis* (a dock), *Anthemis ætnensis* (a camomile),† *Robertsia taraxacoides*, and various lichens (*Stereocaulon vesuvianum*, etc.).

Above this region all is barren, lava, black sand, scoriæ, ashes, etc., an unutterably dreary

* Von Waltershausen: "Atlas des Ætna" (1849—1859).

† The last three named plants are peculiar to Etna. The groundsel ascends to within a short distance of the crater, considerably higher than the Casa Inglesi, which is at a height of 9,652 feet above the sea.

waste,* covered with snow three-fourths of the year; even in summer, when the volcano happens to be quiescent, banks of snow and blocks of ice may be found in shady rifts among the black blocks of lava close to the crater. Examples of similar zones, varying in height, and in the species characterising them, might be cited from many other parts of the world, from the Caucasus, Persia, the Atlas in Morocco, though it does not enjoy a perpetual snow cap, from Mount Cook, the loftiest peak in New Zealand, from the Himalayas, from the Rocky Mountains, Cascades, and Sierra Nevadas in America, many of which are dotted by very lofty peaks, and from Kilimanjaro in Central Africa. It is, however, unnecessary to cover much more ground, as the facts which we have endeavoured to convey must, by this time, be sufficiently clear to the reader.

At an elevation of 5,900 feet the last banana plantation is passed on Kilimanjaro, when a forest region is entered, this zone reaching a height of about 11,000 feet. Grass-covered lava fields follow, and seem to extend to between 15,000 and 16,000 feet; after which lichens and mosses take their place, until snow and ice stop the upward range of life.† In the Himalayas, Madden and Strachey found, in proceeding from the plains of India through Kumaon to Tibet, that the forms of temperate climates gradually appear above 3,000 feet, in the shape of species of pine, rose, bramble, oak, barberry, primrose, etc. At 5,000 feet, oaks, rhododendrons, andromedas, cypresses, and pines, replace the trees of the plains. At 8,700 feet the European character of the vegetation is thoroughly established, and, though species identical with those of Europe are rare, representative forms are frequent. From 7,000 to 11,000 feet, oaks, horse-chestnuts, elms, maples, pines, yews, and hazels, the latter large trees, are the most frequent members of this Alpine forest zone. At about 11,500 feet the forest ends; *Picea webbiana* (a conifer), and *Betula bhojpatra* (a birch), being usually the last trees. For about 1,000 feet more shrubs continue in abundance, but at 12,000 feet herbaceous plants are the most important representatives of vegetation. At 15,500 feet —on the southern face of the mountains—the snow-line is reached, the last flowering plants being a species of *Echinospermum*, which keep a footing at 17,500 feet, and an *Urtica* (nettle), common at the same elevation when the snow-line happens to recede to 18,000 or 19,000 feet. The cultivation of barley is carried on at 14,000 feet, and turnips and radishes, under very exceptional circumstances, can be grown at nearly 16,000 feet above the sea.

The upper limits of the successive zones of vegetation on a mountain side are, like the polar limits of plants, determined mainly by temperature. To some extent, however, the dampness of the air has an influence on the upward range of certain species; some forms which delight in an atmosphere of the former kind finding it in the dry atmosphere of great heights. The inferior bounds of these zones are much more vague and difficult to determine, as are also the causes limiting them. But the entire question of the origin of the Alpine flora will be considered in a later chapter, when we come to consider the influence of the Glacial Period on the dissemination of Northern plants.

* "The charred, blackened, melancholy waste,
Crowned by the awful peak, Etna's great mouth,"

of Matthew Arnold; or as Claudian described it fourteen hundred years ago—and it has altered very little since then—

"Pars cetera frondet
Arboribus: teritur nullo cultore cacumen."

† Meyer, Petermann's *Geographische Mittheilungen*, 1887, and "Zum Schneedom des Kilimandscharo" (1888).

CHAPTER XVIII.

The Distribution of Plants into Botanical Regions.

Various attempts to mark out Regions dependent on Physical Boundaries, or Based on the Descent of the Present Floras from Pre-existing Ones—Schouw's—Grisebach's—Bentham's—Engler's—Drude's—Description of these—The Distribution of Marine Plants in Area and in Depth—Area of Genera and Orders—Wide Distribution of Cryptogamic Plants—Examples of this Extensive Range—Generalisations arrived at regarding the Laws Regulating the Distribution of Different Groups—Illustrations of these Laws by Examples from the History of the Genus Asplenium—Distribution of Orders Illustrated by that of the Palms—Statistics of Vegetation—The Number of Species of Plants known to the Ancients, and the Approximate Number known to Exist at the Present Time—The Ratio of Dicotyledons to Monocotyledons—What Circumstances tend to make one Region Richer in Species than Another—Mistaken Popular Ideas regarding the Richness of Tropical Forests in Flowering Plants—Reasons why this is not the Case—A Country may have an Exuberant Vegetation, a Wealth of Individuals, but be Poor in Species—Number of Plants in a Square Mile in Different Regions—Examples from the Floras of Various Countries—Proportion of Species belonging to Different Orders in Different Parts of the World—Limits of Vegetation, etc.

In the preceding chapter we have considered the distribution of plants mainly as effected by climatic conditions. It is, however, evident that the various floras of the world are due to other causes besides those dependent on the distance of any region from the Equator. If we could imagine the globe to be covered by land and water in exactly the same proportions, and the land to be of a uniform height throughout, then the zones of plant life, which more or less theoretically exist, might be found to extend north and south of the Equator in regular bands, graduating into each other according to the varied temperature and moisture which prevailed in the different latitudes. But this, we know, is not the case. Land and water are very irregularly distributed, and the elevation of the surface of the globe varies greatly, so that the isothermal lines (*see* Plate) do not follow the lines of latitude any more than do the zones of vegetation. Still further, we find on examining the vegetation of the globe, that there have been causes constantly at work in the history of the earth which have infinitely varied the original distribution of plants, so that the species of one region have invaded those of another, by the breaking down of the barriers at one time separating them, or by the creation of conditions rendering it possible for these migrations to take place, and to remain permanent. It is also clear that the present distribution of vegetation dates from a period preceding the modern arrangement of land and water, islands now dissevered from continents having been at one time—as their plants and animals show—united with them, the intervening land with the connecting links between the floras of regions being now sunk under the sea. In brief, we must go back to times preceding our own, in order to gain some insight regarding the origin and distribution of the vegetation covering the earth, which, we know, has, in the course of the long ages during which it has been evolving, undergone innumerable changes in its physical features.

The result is, that though climate, isolation, and other causes, have rendered a particular region notable for what looks at first sight as a flora altogether peculiar to itself, it is often found that these appearances are altogether superficial, and that underneath the surface there lie features which prove that the more prominent species which seem to characterise the district are not the true aborigines, but immigrants of a more or less remote date, and that the real connections of the flora are with others now separated from it by seas, and other impassable barriers. Add to this the fact that the transporting agents already described have always been at work, and it will

be seen that to separate the native forms from the foreign ones is extremely difficult, while to go far back in geological times and try to trace their genealogy from extinct forms becomes still more puzzling. Indeed, in the present state of our knowledge it is so nearly impossible, that most phyto-geographers have preferred to map out the distribution of plants without taking into consideration their supposed relationship to other forms, or to plant migrations in the most recent geological period. In doing so they follow the practice of ethnographers, who delineate the modern distribution of races without concerning themselves very much about the predecessors of these tribes and nations, though they are well aware that the regions now covered by the various European peoples were at one time (pp. 242–268) the home of others who have either disappeared or become amalgamated with their successors.

The earlier attempts at mapping out the world into plant regions took into consideration solely the present distribution, and attributed this entirely to climate and other physical conditions and barriers. It also followed that, as they differed as to the importance of certain groups in characterising certain regions, the maps thus constructed, though essentially the same in some particulars, varied widely in others. Schouw,* for example, whose views were at one time very generally espoused, divided the world into twenty-four regions, each distinguished by the prevalence of some particular order or orders, and named in compliment to the botanist whose reputation was connected with its exploration; and not to mention numbers of others of less account, Grisebach† portioned the world into twenty-five great provinces, the boundaries of which he attributed almost entirely to climatic conditions. However, since the wide acceptance of Darwin's views, either wholly or in part, later phyto-geographers, such as Bentham, Hooker, Asa Gray, Engler, and Drude, have attempted to go behind the present condition of matters, and, in tracing out the distribution of existing plants, to take pre-existing life and geological revolutions into account. Bentham was the first to make this attempt, and all who have followed him, though differing in the details of their plant regions, and in the conclusions at which they arrived, have more or less based their researches on his.‡

Bentham's Botanical Regions.—"There are," this celebrated botanist tells us, "regions of vegetation depending on physical and climatological considerations which influence chiefly the areas of individual species or varieties, and botanical regions depending on community of origin or genera. By the combined effort of these two agents, wherever the uniform action of the one upon the other has been promoted by the continuance of geological repose and maintenance of impassable barriers, so many species, genera, or even natural orders, have been gradually produced or introduced, and maintained in certain territories, whilst they have never appeared or have become extinguished in others, as to have given to every territory or district a special botanical character; and thus real regions have been formed exceedingly unequal in size, definiteness of circumscription, and intensity of specialisation (distinctness of character), but which it is very instructive to study and compare, and must, therefore, be named and described. We must also admit that every race has probably been the offspring of one parent or pair of parents, and, consequently, originated in one spot; but we must also insist that it may have been widely spread for years or ages before it became finally differentiated — perhaps under conditions and in countries different from that which gave it birth—and that the idea of general centres of creation whence the flora of a region has gradually spread is a perfect delusion." These words express in a condensed form Bentham's ideas of the three great regions with which he proposed to supplant

* "Grundzüge einer allgemeinen Pflanzengeographie" (1823). † "Die Vegetation der Erde nach ihrer klimatischen Anordnung" (1872). His map is engraved in "Science for All," Vol. IV., frontispiece.

‡ *Presidential Address to the Linnean Society*, 1869.

the districts of vegetation mapped out by Schouw, Grisebach, and others, including himself.

He accordingly divides the globe into three great botanical areas, corresponding very closely to the zoological ones, if due allowance is made for the greater antiquity as well as for the greater facility of dispersion enjoyed by plants over animals. These regions may be regarded as having existed from the earliest times, though the character of their vegetation has altered infinitely at different periods. They are as follows :—

(1), **A Northern Type**, distinguished by needle-leaved Coniferæ, Amentaceæ,* Ranunculaceæ, Cruciferæ (mustard and turnip order), Trifolieæ (clover tribe), and other herbaceous races spreading over Europe and Northern Central Asia, and a portion of North America (long since broken up into two by the irruption of the North Pacific Ocean, and the upheaval of the Rocky Mountains chain). In this type of distribution Bentham thinks there is some evidence of an ancient continuity of vegetation with gradual change from Eastern North America to Eastern North Asia, somewhat analogous to that now observable from Eastern Asia to Western Europe. Since this disruption that divergence of floras once identical, which distance alone will produce even without disseverance, has increased by isolation. In Asia, especially in Japan, Manchuria, and the Himalayas, a few races like Phryma have maintained their absolute identity; but a large number are altered so as to produce those geographical varieties, or "representative species," the nature of which Asa Gray has discussed.† Races of a higher order, genera like *Astragalus*,‡ have multiplied largely in both divisions, retaining some identity in the high Northern and Alpine species, with a greater divergence in the temperate and warmer portions of their respective areas, which have probably been longer dissevered, or into which the genus may have independently spread in the two hemispheres

Fig. 241.—THE SHRUBBY HEATH (*Erica arborea*), ONE OF THE CHARACTERISTIC PLANTS OF THE MEDITERRANEAN REGION.

a, Flowering branch; *b*, Flower; *c*, *d*, Parts of the Flower (enlarged).

without further communication. Other genera, like *Eupatorium*,§ *Aster*, *Phlox*, *Solanum* (potato genus), etc., very numerously represented in America, have transmitted or produced a smaller number in Eastern Asia, gradually diminishing westward till they disappear altogether, or reach Western Europe in single species but little altered from the American ones. The Europeo-Asiatic genera, on the other hand, our Cruciferæ, Carophyllaceæ,

* Willows (Salicaceæ). Hazels (Corylaceæ), Birches (Betulaceæ), Myricaceæ, and other plants, whose flowers grow in catkins or amenta.

† *Memoirs of the American Academy of Arts and Sciences*, Vol. VI., *n. s.*, Vol. VI., pp. 377–458; "Darwiniana," pp. 219–224; *Bulletin United States Geological and Geographical Survey*, Vol. VI., p. 1; Bentham, *Presidential Address to the Linnean Society* (1872), pp. 5–7, etc.

‡ Gum tragacanth exudes from the bark of a species of *Astragalus* (*A. gummifer*) of Persia, Asia Minor, etc.

§ The genus to which hemp agrimony (*E. cannabinum*), the Peruvian styptic "matico" (*E. glutinosum*), and the tonic *E. perfoliatum*, well known in the Eastern United States, belong.

Loteæ, Umbelliferæ, etc., which have increased so largely on this side of the Pacific, appear to have left but few representatives in America, and those much more modified than the American races left in Asia. These suggestions of Bentham are no doubt purely speculations, and founded on the hypothesis of the mutability of species indefinitely throughout long ages; yet they are worthy of grave consideration, entering as they do into some of the deepest questions which the scientific botanist, as distinguished from the mere hair-splitter and namer of species, is called upon to face. Where this Northern Flora originated, or whether it ought to be termed Scandinavian, or North Asiatic, or Caucasian, are still moot questions. As we have indicated (p. 330), it is probably one of the oldest of existing floras, and once extended much farther south. Besides the above mentioned great disseverance of this flora east and west of the Pacific, Bentham points out that physical and climatological conditions have, by their long duration, acting in concert with other causes, produced three marked secondary types, namely: (*a*) *The Cold* or *Alpine-Arctic*, (*b*) *The Hot* or *Mediterraneo-Caucasian*, and (*c*) *The Intermediate* or *Temperate*—the two former with a large number of locally restricted individually persistent species,—with evidence of great antiquity in their present stations, the Temperate with a much more uniform and widely spread flora, in many places comparatively recent or so-called derivative (Fig. 241).

(2), **A Tropical Type**, characterised by arborescent *Polypetalæ* and gigantic monocotyledons. This flora is divided into three subdivisions, corresponding with the three tropical continents. (*a*), *Africa* forms a puzzle to the phyto-geographer. In the vegetation of tropical Africa there are many Asiatic types —and even in the interior a certain number of American ones—offering a problem as yet unsolved. The relationship of the Madagascar flora (Fig. 261) to that of Africa is well marked. Yet, just as we find in the island an immigrant Malay race (the Hovas), so do we discover among the native stock Indo-Malayan types, which, as in the case of *Nepenthes* (the pitcher plant genus), connect it with that of the Mascarene Islands, while it contains several Asiatic types which do not

Fig. 242.—THE TEA-PLANT (*Thea sinensis*), A NOTABLE PLANT OF THE EAST ASIATIC FLORAL REGION.

extend to the neighbouring continent. On the other hand, its upland flora is closely allied to that of the Alps of Central Africa and the Cape.

(*b*), *America* (Figs. 230, 256, 258, 259, 260).

(*c*), *Asia*, comprehending India, most of China, southern Japan, and the Malay Islands, with the doubtful exception of New Guinea. But it includes Polynesia to the north and east of the islands belonging to Australia.

Altogether, there is reason for believing, from the presence of the same well-marked types in the Old and New World temperate floras, though these do not extend into the temperate flora of either region, that the tropical vegetation of the two continents had at some time a common origin. Mr. Darwin, indeed, suggests that the modern tropical flora is the blended and diminished residue

of two sub-tropical floras, occupying the place of a more ancient one which has now disappeared.

(3), **A Southern Type,** connected, in remote ages, by its Restiaceæ, Proteaceæ, Ericaceæ (heath order), single-leaved Papilionaceæ, Diosmeæ, etc., "but long since differentiated by the total want of identity in the subordinate races of these identical higher ones, as well as by the exclusive abundance of Myrtaceæ and many smaller groups in the Australian portion," seems, more or less, to agree with the North and South Zoological Divisions of Huxley,* with the East and West of Sclater,† and with the three "Hauptfaunen" of Gabriel Koch.‡ From a study of this flora, Bentham thinks that he can detect four subordinate types :—

(*a*), *An (Andine) Antarctic Alpine Flora,* which, with a few members of the great Northern type, but with a large number of genera of its own—*Fuchsia, Gaultheria, Calceolaria, Ourisia,* and many others,—ranges, more or less, along the whole chain of the Andes, though interrupted at present by the depression of Central America, but penetrating, in some species, far northward into North-West America (which region, however, in general, belongs to the Northern type), throwing off a few branches into Eastern Asia, and its southern extremity crossing over to New Zealand, and, in smaller numbers, to Tasmania and the mountains of Victoria. On the Antarctic Islands are found local species and genera of some widely-distributed Northern orders—*Pringlea, Lyallia, Cotula,* etc. (Fig. 253).

(*b*), *A less Cold, but still Non-Tropical Vegetation,* few in numbers, but often represented at great distances by closely allied species of small distinct genera. It is represented in Mexico and California, in the Argentine States, and in South Africa or New Zealand, there being more nearly allied species between North Mexico and the Argentine States, or between the latter and South Africa or Australia, than there are between the two latter (Fig. 254).

(*c*), *The Australian Flora,* almost endemic, showing some slight connection with New Zealand, and a few remains of former ramifi-

Fig. 243.—THE COMMON COTTON PLANT (*Gossypium herbaceum*), a native of Eastern Asia, and a characteristic cultivated plant of the flora of that region.

a, Flowering twig (enlarged); *b*, Pistil and ovary at the base; *c*, Pod full of cotton; *d*, Same, showing the cotton hairs around the seed (on a small scale).

cations northward to some parts of the Indian Archipelago, a very few species, perhaps of modern introduction, extending to China and Japan. To this flora belong the Gum tree (*Eucalyptus*), the Grass tree (*Xanthorrhœa*), the Bottle tree (Fig. 255), the *Banksia, Hakea, Dryandra,* and other proteaceous forms; the Acacias, with the edges of their leaf-like phyllodes turned to the sky; the Epacrids, and other well-known plants. All of these are of very ancient types. Indeed, the flora of Australia seems to have existed, isolated by the breaking down of all the links connecting it with that of other regions, from a very

* *Proceedings of the Zoological Society,* May, 1868.

† *Journal of the Linnean Society,* Vol. II. (Zoology).

‡ "Indo-australische Lepidopteren-Fauna in ihren Zusammenhang mit der europäischen, nebst den drei Hauptfaunen des Erde" (1865).

early date. Most probably it lasted very much in its present form all through the Tertiary Period, and may have originated in the North, where plants of a like character occur in the earlier Tertiary beds * (Fig. 142).

(*d*), *The South African Flora* is the fourth sub-type which Bentham recognises in the Great Southern type, perhaps the richest known flora in proportion to its extent. Several of the characteristic genera, with hundreds of species, in the south-west, have nearly or entirely disappeared at Durban on the east, and before we reach the tropical line to the north-west. It has a very slight connection with other flora, a very few species, on the one hand, connecting it with Australia, and, on the other, a few scattered types representing it in Extra-tropical South America. It is also related to the flora of North Africa and Western Europe by various shrubby Leguminosæ and Ericas, Lobelias and Gladioli—"more nearly allied to corresponding Cape species than they are to each other"—and with the sub-Alpine flora of Kilimanjaro and other lofty Central African mountains (p. 338); so that, as Hooker suggests, it is not unlikely that the South African flora was at one time continuous all over the highlands of East Africa from Natal to Abyssinia. The same species are also found on the Cameroons, a mountain in West Africa 17,360 feet high (Figs. 206, 207, 216, 220, 221, 237, 252).

Engler's Regions.—In 1882 Dr. Adolph Engler, of Kiel, proceeded a step farther in the same direction in constructing the map which we have reproduced. It professes to sketch the regions of vegetation according to the order in which they have been developed since the close of the Tertiary Period, when the principal European, South American, and Asiatic ranges, were developed. Accordingly, he divides the existing floras into (*a*), *Arcto-Tertiary;* (*b*), *Palæotropical;* (*c*), *Neotropical;* and (*d*), *Older Oceanic Elements*, according to the types of these floras which prevail in them.

The Arcto-Tertiary can be traced as far North as 81°, in the Miocene beds of Grinnell Land (p. 217), and over wide circumpolar districts of Europe, Asia, and North America. Here we see numerous coniferæ, various species of trees and shrubs, most of them mesothermic (p. 275) plants.

The Palæotropical Element is referable to the Tropics of the Old World, where originated many important families, such as those of the Palms, Screw-pines, Dracænæ, Mimoseæ,

Fig. 244.—THE SOUTHERN SEA-GRASS (*Posidonia caulini*). A MARINE FLOWERING PLANT.

a, Flowering plant; *b*, Root stock; *c*, Separate flower; *d*, Stamen; *e*, Stigma.

Myrtles, Myricaceæ, Araliaceæ, etc. In Africa the existence of Caprifoliaceæ and Rhodoraceæ indicates a former connection of that continent with Southern Europe. In Fig. 223 we have a typical view of Palæotropical vegetation in the primeval forest of Boninsima, one of the Bonin Islands, which is very much what we find in the Caroline and Marianne Islands—tropical vegetation, with a few plants of the temperate zone.

The Neotropical or South American Element

* Hooker: "Introduction to the Flora of Australia," p. cii.; Bentham: "Flora of Australia," Vol. VII., p. v.

is seen in the Tropics of Brazil and in the West Indies.

The Old Oceanic Element is found in large portions of the Southern Ocean, as in Australia (Figs. 195, 212, etc.), which, with a flora essentially its own from the earliest times, possesses a few intrusive South American elements. In the map these regions and their subordinate districts are sketched so fully that it is unnecessary to recapitulate them.*

Engler, in brief, like Bentham and most other modern botanists, regards the modern flora as a mere reminiscence or development of the old Tertiary flora, which has been

Fig. 245.—THE TWIN-BLADDERED WRACK (*Fucus vesiculosus*).

a, Piece with the fruit; *b*, Piece with air-bladders.

sketched in the preceding pages, and considers that the regions he has divided it into are—allowing for later immigrations—mainly those which held good at the close of the Tertiary Period, when the broad physical features of the world had pretty well taken their present form; the great continental masses having always been tolerably permanent. The smaller districts, the outlines of which are shown on the map, may be regarded as the result of local circumstances operating since that Period.

Drude's Regions.—The latest attempt to

Fig. 246.—THE FLOATING "GULF WEEDS."

a, The common Sargassum bacciferum; *b*, Another species (S. podacanthum); *c*, Under-surface of a magnified frond.

divide the vegetation of the globe into regions and minor sub-divisions is that of Dr. Oscar Drude of Dresden.† He, like his predecessors, allows that the present plant life of the earth is derived from the Tertiary flora, and that, in analysing its elements, consideration must be paid to this circumstance. In, however, arranging the different floras it will be seen from the map, which is reproduced from his original, that he takes a somewhat different

* Engler: "Versuch einer Entwickelungs geschichte der Pflanzenwelt; insbesondere der Florengebiete seit der Tertiärperiode" (1879—82).

† Petermann's *Geographische Mittheilungen*, 1884. (Ergänzungheft, 74.)

view of the limits of the different floral provinces, which, in some respects, correspond with those into which animals arrange themselves north and south of the Equator (Figs. 242, 243, 247, 248, etc.).

The Oceanic Flora.—This comprises the numerous species of seaweeds (Algæ), either stationary like the majority of the species or floating like the Sargassum, which covers so large a section of the tropical Atlantic known as the "Sargasso Sea" (Fig. 246), and the true flowering plants like the sea-grasses (Fig. 244).

Distribution of Marine Plants.—(1) *In area.* From the peculiar facility which the sea affords for the spread of the zoospores of Algæ, this order, which contains from 4,000 to 5,000 species, is very widely scattered. Still, however, among them, as among land plants, there are certain general laws of distribution which can be pointed out. But, unlike land plants, they seem equally abundant in *individuals* in the frozen sea and in the warm waters of the tropics. The *species*, however, in the former zones are much fewer than in the latter. Drude recognises three oceanic regions:—(1) The *Northern*, divided into (*a*) Arctic coast, (*b*) the North Atlantic coast, (*c*) the North Pacific coast; (2) The *Tropical:* (*d*) Mediterranean coast, (*e*) Tropical-Atlantic coast, (*f*) Indian coast, (*g*) Tropical Pacific coast; (3) *Austral:* (*h*) Austral-Asiatic coast, (*i*) Antarctic coast.

The student must, however, remember that these "regions" are to be looked upon as only approximately—not absolutely—defined, and to be subject to the same objections we stated in a former section (p. 339) when speaking of the regions of terrestrial vegetation. In general terms it may be said that the distribution of marine plants is much more general than that of land ones. For instance, upwards of thirty species of Algæ are common to Britain and New Zealand (one-fifth of the Antarctic Algæ, including those of New Zealand and Tasmania, being British species also).* The Porphyras and Ulvas (lavers) of the British coast are found quite as familiarly at the Cape of Good Hope.

North and south alike these weeds flourish in great luxuriance. *Chorda Filum* is in the North Sea found occupying spaces 600 feet broad, and from 15 to 20 miles in length; while in the tropics *Sargassum bacciferum* (Fig. 246), which is the principal species composing the "Sargasso Sea," spreads over an area of 260,000 square miles. The tribe of *Fucoideæ* are more common toward the Poles, as *Laminariæ*, oarweeds, or tangle, are most frequent and of greatest size in the Southern seas. *Nereocystis* † again is characteristic of the North Pacific, where the sea-otter may often be seen resting on its great tangled masses; while the huge *Macrocystis pyrifera*, though common in the South Pacific, is not confined to any latitude. A narrow isthmus is infinitely more unfavourable to the migration of marine plants than a gulf of similar extent would be to land species. Accordingly, we find that the Caulerpas and Sargassums of the Red Sea are different from those of the Mediterranean. It has also been noted that the genus *Fucus*, so common in the Atlantic, is found very sparingly in the Mediterranean.

(2) *Bathymetrically.*—As terrestrial plants are distributed in vertical zones, so marine plants have certain zones of distribution according to depth—this being called the *bathymetrical* ‡ distribution of Algæ. Along the British and European coasts generally the following are the zones pointed out by Edward Forbes:—1. The *Littoral Zone*, very uniform around the Northern Hemisphere, and lying between high- and low-water mark; distinguished by species of *Fuci*. It may be further divided into: (*a*) The sub-region of *Fucus canaliculatus;* (*b*) The sub-region of *Rivularia;* (*c*) The sub-region of *Chylocladia articulata, Fucus nodosus,* and *Corallina*

* Sir Joseph Hooker has suggested that the Antarctic species may be transported to the Arctic seas by means of the cold currents which prevail from Cape Horn to the Equator, and are there met by other cold waters from the north.

† The Indians make fishing-lines of its long cord-like fronds, just as at one time the same use was made of *Chorda Filum* by the Scottish islanders.

‡ Greek, *bathys*, deep; and *metron*, measure.

officinalis; (*d*) The sub-region of *Fucus serratus*. 2. The *Laminarian Zone*, extending from seven to fifteen fathoms, distinguished by the Laminarias and deeper sea fuci. 3. The *Coralline Zone*, which ranges from fifteen fathoms to the lowest depth at which marine plants have been found. This zone is in the British sea very little marked, and when present is distinguished by Melobesias and other coralline-like Algæ, which are known as "lithophytes," or "stone plants." In the Mediterranean it ranges from fifty to one hundred fathoms (Vol. I., p. 352).

Again, on the north-east shores of North America six zones may be traced:—(1), The Drift or Beach Zone, which, however, scarcely deserves that name, since it is composed of the "jetsam and flotsam" thrown up by the waves; (2), The *Ulva* or Laver Zone, distinguished by bright-coloured species of Algæ belonging to this and allied genera; (3), The Fucus or Sea-Wrack Zone, divided into three sub-zones —those marked by *Fucus nodosus* (the nobbed fucus), *F. vesiculosus* (the twin-bladdered sea-wrack, Fig. 245), and *F. furcatus* (the forked fucus, a species not found on British shores). (4), The Laminarian or Tangle Zone; (5), The Chondrus or "Irish Moss" Zone; and (6), The Deep-sea Zone, distinguished by some plants belonging to genera found in the other zones, and by species not found in shallow water. In the first category comes *Laminaria longicruris*, and in the second *Rhodomela subfusca*, a species very commonly distributed round the British coasts between tide marks, and *Euthora cristata* (the analogue of the European *Plocamium coccineum*, a bright red species commonly seen in all collections of seaweeds), the *Delesserias*, etc.*

Seaweeds, however, reach a much smaller depth than marine animals. From high-water mark to twenty fathoms is the usual depth at which they live; very few reach from forty to sixty fathoms; and unless we except corallines and nullipores—species covered with carbonate of lime (Vol. I., p. 55), which consolidate into rock-like masses—few, if any, it was the experience of the *Challenger* and other deep-sea dredging Expeditions, exist beyond 150 fathoms.

Depth has some effect on the colour of the species, freshwater and shallow-growing Algæ being generally green, olive-coloured species abound between tide marks, while the red ones are found chiefly in the deeper parts of the sea. That light penetrates to a greater depth than 400 fathoms is doubtful. Yet bright-hued animals with sensitive eyes have been brought up from a depth of at least 2,200 fathoms, thus overturning all our former ideas on the subject of the bathymetrical distribution of organisms.

Distribution of Sea-grasses.—The distribution of the sea-grasses (Zosteraceæ), the only order of flowering plants found in the sea, has already been referred to (p. 346). They are usually found in the Laminarian Zone, but sometimes go to a greater depth, *Posidonia oceanica*, L., having been found in the Quarnero Gulf at from fifteen to thirty-five fathoms.† Altogether, of the eight genera and twenty-two species, fourteen are found in the Indian Ocean and thirteen in the warmer parts of the Pacific. In the Atlantic seven species live; while in the Northern Ocean only our common sea or eel-grass (*Zostera marina*) flourishes ‡ (Fig. 244).

The species of *Sargassum* (Fig. 246) are among the most remarkable, one or two of the many forms supplying the greater mass of the floating seaweeds which cover the Sargasso Sea, that oceanic area which so amazed the seamen of Columbus, who could not understand how they had reached sea-wrack and yet were still afloat. At one time this enormous mass of "Gulf weed" was thought to have been wrenched from the shores of Bahama and Florida, and carried to the place where it now floats by means of the Gulf Stream. But the chances are that at one time it grew on a land surface now submerged, and that in course of time the Algæ have adapted

* Kemp, *Canadian Naturalist*, Vol. VII., pp. 20–24.

† *Physikalische Verhältnisse und Vertheilung der Organismen im Quarnerischen Golf* (1863), p. 249.

‡ Ascherson, in *Geographische Mittheilungen*, 1871, pp. 242–8; Alex. Agassiz: "Cruises of the *Blake*" (1888).

themselves to their surroundings, since they now live and propagate freely on the surface of the ocean, sheltering in their thick masses great quantities of marine animals, which afford apt instances, as Sir Wyville Thomson tells us, of protective resemblances, the species, in colour, looking so like the Gulf weed that they do not readily attract the keen-eyed sea birds, to which they would otherwise fall an easy prey.

Fig. 247.—DIAPENSIA LAPPONICA, a plant characteristic of the Northern Flora, originally discovered in Lapland, but now known to exist in many other parts of Northern Europe, Asia, including Japan, and in America as far south as the White Mountains, in New Hampshire.

a, The plant, of the natural size; *b*, Longitudinal section of a flower; *c*, Perfect flower. (The two latter are enlarged.)

Area of Genera, Orders, etc.—In collating the data upon which the preceding generalisations have been based, we arrive at some interesting conclusions regarding the manner in which the genera of plants, and the larger groups to which they belong, are distributed over the earth. The lower cryptogams—fungi, mosses, lichens, and seaweeds—are the plants most widely distributed, their simple organisation enabling them to brave almost any climate, and to pass from region to region with a facility denied to more complexly-formed species. Indeed, some species appear to be almost cosmopolitan, the lightness of their spores and the simplicity of their structure giving them every facility for spreading over wide spaces of country and to high elevations. So rapidly are they disseminated, that at one time fungi were supposed, from their springing up in places the most unexpected, to be "spontaneous" in their generation. The spores of fungi are so exceedingly small that a discharge of them appears like a jet of smoke. For instance, Elias Fries says that in a single individual of *Reticularia maxima* he has counted 10,000,000, and that these are so light as to be raised, perhaps, by mere evaporation, and dispersed by the slightest breath of wind, by insects, elasticity, adhesion, etc., so that they could be excluded from almost no place. Lichens, mosses, and liver-worts are even more cosmopolitan in their distribution than fungi. Almost all the Antarctic lichens known are also inhabitants of the Northern Hemisphere, and most are also European. *Lycopodium cernuum* (a club-moss) is almost uniformly distributed over all equinoctial countries. The higher cryptogams, like ferns,

Fig. 248.—THE ROSY SALTWORT (*Salsola rosacea*), a plant characteristic of the Steppe Flora of Central Asia.

a, Fruiting twig; *b*, Flowering twig; *c*, Flower; *d*, Fruit, with wing; *e*, The spirally-twisted embryo; (*c*—*e*, magnified).

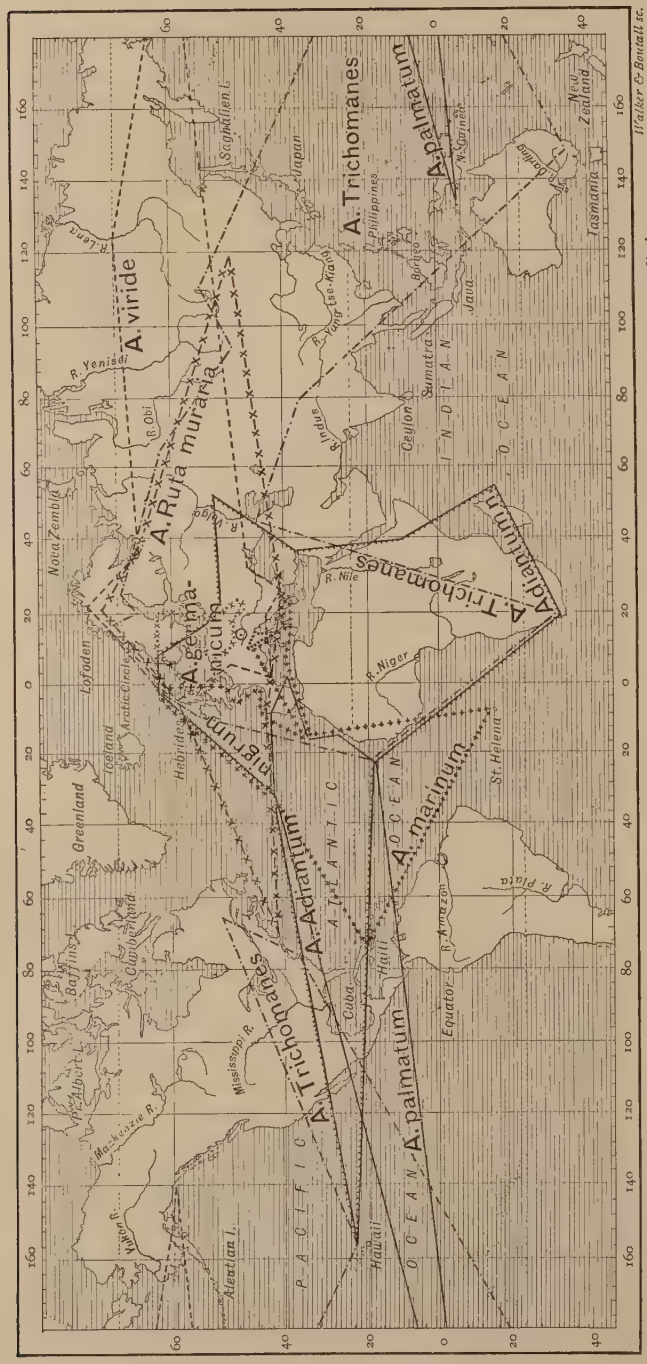
horse-tails, club-mosses, etc., are by no means so generally distributed as the lowest orders. Ferns especially are much governed in their range by the amount of vapour in the atmosphere.*

The higher cryptogams, however, only obey the law that universality of distribution is in an inverse ratio to complexity of structure, for flowering plants are still more restricted in their distribution than ferns and their allies, while monocotyledons—the lower division of flowering plants—enjoy a wider area than the higher dicotyledons (pp. 271, 315).

A few of the other generalisations which have been deduced are as follows:—(1), As regards stations, De Candolle has arrived at the inference that the area of aquatic plants is wider than that of any others, the only exception being the Algæ-like *Characeæ*, which are very localised. Notwithstanding the barriers of sea and land between freshwater lakes and rivers, there is a great similarity of aquatic beings over the world—though this is contrary to what we would have expected to find. Some plants have enormously wide range. De Candolle remarks that this is shown in some large groups which have only a very few aquatic members, but which, in consequence, have a very extended area. The earth which adheres to the feet of wading birds which are sure to fly to their natural haunts rapidly—most likely without halting in the sea—is one of the chief causes which conduce to this (p. 299). Aquatic birds also, as has been already remarked (p. 301), swallow fishes with freshwater plant seeds in their stomachs, and eject them often in some far distant lake, river, or other piece of water. Furthermore, in aquatic plants we find "hibernacula," or reproductive buds, which, like seeds, lie long dormant, and can be transported to immense distances; of this the invasion of Great Britain by *Anacharis Alsinastrum* (p. 286) is a striking example. Next to aquatic plants in wideness of area are those orders which contain many plants which have their station in very marshy or humid places, or in saline ground by the seashore. Then come plants of cultivated lands, waste heaps, walls, and hedgerows, which follow man's footsteps over nearly all the world, and hence have a vast range. Finally come those of arid lands, deserts, and uncultivated places generally (pp. 319, 320). (2), *In reference to duration and size of the plants.* Among flowering plants, annuals have the widest area, then herbaceous plants, then shrubs and bushes, and lastly trees. So that in general language the area of flowering plants is larger as the plants are small, and their duration of life shorter. (3), *In reference to fruit and seed.* Though some families, the seeds of which are furnished with the means of flight (such as *Apocynaceæ, Bignoniaceæ, Œnotheraceæ,* etc.), are very widely distributed, yet, as already hinted, it cannot be stated as a general law that the plants whose seeds are provided with wings, pappi, hooks, or other apparently special means of being easily transported great distances, have a wider area than those not so furnished. Indeed, in some cases the contrary seems the case (p. 303). The weight of the seed itself appears to have a more important bearing on this.

The general conclusions arrived at are:—(1), That no species of flowering plant grows in every part of the world. Some may be found in the Arctic and temperate regions, and then, after vanishing over a wide intervening region, reappear in the Southern temperate and Antarctic regions, but none are found from pole to pole. Some, we have seen (pp. 315, 317), are extremely restricted in their range, and a few have, so far as our knowledge extends, an area limited to only a few feet of earth, so that we are justified in regarding them as vanishing from it. In addition to those already enumerated (p. 271), the case of the Macpalxochetlquahuitl of the Mexicans (*Cheirostemon platanoides*) may be alluded to in this relation. This plant is

* On the distribution of ferns, the reader is referred to Mr. J. G. Baker's memoir in the *Transactions of the Linnean Society*, Vol. XXVI., p. 374, and to Sir Joseph Hooker's notes to Berkley's "Cryptogamic Botany," p. 516, in which work also will be found a good account of the distribution of the cryptogamia in general.



Asplenium: 1. Palmatum 2. Marinum 3. Viride 4. Trichomanes 5. Petrarchæ 6. Germanicum 7. Adiantum nigrum 8. Ruta muraria 9. Heufleri

Fig. 249.—DISTRIBUTION OF THE EUROPEAN SPECIES OF ASPLENIUM, OR SPLEENWORT FERN.

(According to Baron Ludwig von Heufler).

the sole representative of its genus, which belongs to the order Sterculiaceæ. It is a tree thirty or forty feet in height, and was at one time known only from a solitary specimen discovered growing near the town of Toluca, and reverenced by the Indians as the tree under which their ancient kings were crowned. It is now more than five hundred years old. But forests of it have of late been discovered near the city of Guatemala, from whence it is rendered probable that the Indians of Toluca had transplanted it in early times. The only known specimen of the *Fokea capensis*, a Cape plant of the order Asclepiadiaceæ, grown in the imperial garden at Schönbrunn, and some years ago a remarkable fungus (*Myelomycetes Schrötteri*, Reiss), made its appearance in an old solution of casein, standing in a laboratory in Vienna, and has never been seen since, just as the only known species of fresh-water jelly fish is confined to the *Victoria regia* tanks of the Royal Botanical Society's Garden in London. These, and other supposed "in-

stances of extremely circumscribed range, may be due to our ignorance of the botanical geography of the world, since species at one time believed to be quite as rare are now known to enjoy a comparatively wide distribution. It is, nevertheless, certain that many forms of plants (and animals also) are very local. Some of these we have already noted. The well-known *Wulfenia carinthiaca* is, in like manner, restricted to the upper Gailthal in Carinthia. (2), On the other hand, several species have a very wide range, though the utmost research shows that there are only eighteen which may be said to extend over a space equal to about half the earth. (3), Those which extend over about a third of the known earth do not exceed 117 species. (4), Among the 135 of which the area is largest, none are woody plants. (5), Of these, 108 inhabit chiefly or entirely the temperate or frozen regions of the Northern Hemisphere. (6), A very remarkable fact is that every species which at once exists on two continents is also found on the intermediate islands.

Each species, instead of being scattered about indefinitely, occupies, as a rule, a definite geographical area, so far as the soil, climate, and other physical circumstances, are suitable to its growth. If, for example, we find a plant, like the shepherd's-purse, or the nettle, growing at once in Great Britain and the Himalayas, we are justified in looking for it in the intervening countries, this being so frequently the case in actual fact, that most botanists will agree with Mr. Baker in regarding the apparent exceptions as in no way invalidating the general rule. In like manner, genera, tribes, and natural orders, are distributed throughout definite areas, some of these areas—as the reader will see by consulting Drude's map—being very restricted; these facts being held to favour the theories (1), that each species has origin from a single centre, and (2), that certain genera, tribes, and natural orders, have descended from one common ancestor. Hence the distribution of genera is much wider than that of species, for a genus may contain—*Rubus* the bramble genus, or *Rosa* the rose genus, for example—many species; the genera which are concentrated in area being usually those which contain only a few forms. The genera of widest distribution are *Ranunculus* (buttercups), *Cerastium* (the mouse-ear chickweed), *Carex* (sedge), *Juncus* (rush), *Senecio* (groundsel), *Euphorbia* (spurge), and *Solanum* (potato and nightshade genus). Others, though containing a number of species, are endemic within comparatively narrow limits. *Phyllostegia* (12 species) is, for example, confined to the Sandwich Islands; *Epacris* (30 to 40 species) to Australia, Tasmania, and New Zealand; *Selago* (75 species) to the Cape Colony, etc.

(7), Among the 117 species of plants having a wide distribution, 73 are dicotyledons and 44 monocotyledons, though the former bear to the latter, taking the entire vegetable world into consideration, the proportion of 83 to 17; so that, proportionately, there are more monocotyledons than dicotyledons, with an extended area, a result in keeping with a law already enunciated (p. 349).

(8), The general mean area of flowering plants all over the earth is about $\frac{1}{150}$th of the entire terrestrial surface.*

Some of the laws of distribution, thus succinctly stated in the abstract, may be more graphically illustrated in the concrete by the diagram (Fig. 249) illustrating the way nine European species of the spleenwort fern (*Asplenium* †) are scattered. These are related to each other, and, on the theory mentioned, all must have sprung from a common ancestor,

* Duchartre: "Elements de botanique," p. 102-9.

† This genus of ferns, which derives its popular name from the principal belief at one time entertained that the plants belonging to it exercised a potent influence over the spleen, is one of the largest of the minor groups of its order, the genus, even in the most restricted form, containing about 300 species, mostly evergreens, and frequenting all situations, from lofty mountains to cliffs facing the sea, and old walls and inland rocks. The latter habitat is much affected by the Black Maiden Hair spleenwort (*A. Adiantum nigrum*) and the rue spleenwort (*A. Ruta muraria*), while the sea spleenwort (*A. marinum*) loves the salty breezes, and *A. viride* the mountain air. We shall, however, limit ourselves to the European forms.

the identity of which it is no longer possible to detect. These species, with their range, are shown in the following table:—

Species of ASPLENIUM.	Distribution over		WE : NS.	Home from which spread.
	Degrees of Longitude.	Degrees of Latitude.		
A. palmatum, Lam.	233	50 n. s.	5 : 1	The Atlantic Region.
A. marinum, Lam.	105	76 n. s.	1 : 1	„ „ „
A. viride, Huds.	229	34 n.	7 : 1	Siberia.
A. heufleri, Reich.	1	1 n.	1 : 1	Tyrol.
A. Trichomanes, L.	314	104 n. s.	3 : 1	Eastern Asia.
A. petrarchæ, D.C.	10	6 n.	1 : 1	Italy.
A. germanicum, Weis.	30	20 n.	1 : 1	Germany.
A. Adiantum nigrum, L.	206	64 n. s.	3 : 1	The Atlantic Region.
A. Ruta muraria, L.	159	34 n.	5 : 1	The Mediterranean Region.

The range of orders is even more circumscribed than that of genera (*see* Drude's Map). Cactaceæ are, for example, confined to America, Epacridaceæ to Australia, and Tamarisaceæ to the Northern Hemisphere, though within these limits their range is great, and their species numerous. On the other hand, there are sixteen orders of plants which, among them, compass more than twenty parts of the earth's surface. These consist of dicotyledons, with a few monocotyledons and cryptogams. There are eight orders members of which are found over the whole earth, namely, Cruciferæ, Caryophyllaceæ, Leguminosæ, Compositæ, Scrophulariaceæ, Juncaceæ, Cyperaceæ, and Graminaceæ. Among other widely-distributed orders may be classed Rosaceæ, Umbelliferæ, Saxifrages, Polygonaceæ, Primulaceæ, Amentaceæ, Orchids, and Alismaceæ.

We may illustrate the distribution of one of the larger groups of plants by a map showing that of the palms (Fig. 250) as worked out by Dr. Drude.*

More than 1,000 species of palms are known, representatives of the order covering about half the surface of the earth, north and south of the Equator, species of this order being found, according to Grisebach, in at least twenty different floras. The greater portion of the palms (562 species) are found in the Western, the smaller (400 species) in the Eastern Hemisphere. The largest number of palms found in any one region is the 100 to 200 species natives of the Sunda Islands, the 200 species found in the Moluccas and New Guinea, and a part of South America, in which no less than 180 different kinds occur. From 50 to 100 species find a home in Further India, Hindostan, the cis-equatorial parts of South America, Brazil, Mexico, and the tropical Andes. Palms also occur in elevated situations, their distribution being materially affected by the character of the soil in which they grow. They are often seen near the snow-line, the well-known wax-palm (*Ceroxylon andicola*) occurring at a height of 9,260 feet, being 6,560 feet higher than the elevation to which most palms attain. *Euterpe andicola* also reaches the snow-line in Bolivia and in Nepaul. *Chamærops martiana* ascends to 4,900 feet, while *C. khasyana* is even hardier, since it braves the cold of 8,200 to 9,840 feet of altitude. Europe has only one wild species of palm, the fan-palm or palmetto (*Chamærops humilis*), which is essentially a coast form, though widely distributed. At the same time, other species could grow quite well, so far as the climate is concerned, since the date-palm, whose true home is Arabia and Northern Africa, flourishes in groves at Elche, in Southern Spain. The chief centres from which the palm order has distributed itself seem to be (1), Africa, with Madagascar, the Mascarenes, and the Seychelles; (2), Asia, with its islands, and Australia, each of these

* Petermann's *Geographische Mittheilungen*, 1878, p. 16.

TWILIGHT AT SEA OFF THE COAST OF PORTUGAL (LAT. 40° 29' N, LONG. 10° 0' W.).

HALF AN HOUR AFTER SUNSET AND TOO SOON FOR A VIEW OF THE ZODIACAL LIGHT, MARCH 1, 1872.

(AFTER A PLATE BY C. PIAZZI SMYTH IN VOL. XIV OF "ASTRONOMICAL OBSERVATIONS MADE IN THE ROYAL OBSERVATORY EDINBURGH.")

Fig. 250.—DISTRIBUTION OF THE PALMS.

centres having a number of outlying provinces; (3), America. Yet of the 182 genera and 1,000 species, there is not one common to the Old and New Worlds, while only two of the tribes of palms are found in both, and only three species are known to be common to any two of these centres, though Ettingshausen will have it that the thirty European fossil palms of the Middle Tertiary Period were derived from Asiatic-African or from American species.

Statistics of Vegetation.—Although our knowledge of the botany of several regions of the earth—Tibet, the remoter parts of China, Corea, Formosa, Central Africa, and other remote places—is still imperfect, and the views of botanists as to what forms are species and what mere varieties somewhat at variance, we are now in a position to state approximately the number of different plants which exist. The progress of knowledge in this respect is shown by the fact that, while Hippocrates, the Father of Medical Science (357 B.C.), mentions only 234, and Pliny (A.D. 79) 800, a number not exceeding what Conrad Gesner was acquainted with in the middle of the sixteenth century, 8,551—among which were 7,728 flowering species — were known to Linnæus in 1778. At the present day descriptions exist of about 122,000 species, namely, 85,000 flowering plants and 37,000 cryptogamia, including 6–7,000 Algæ, 6,200 lichens, 2,000 liverworts, 7,400 mosses, 3,200 vascular cryptogams, such as ferns, club-mosses, and horse-tails, and, if De Bary's estimate is correct, about 12,000 fungi or mushrooms, moulds, blights, and species of a like character; though the researches of collectors in regions hitherto imperfectly examined, and even in so thoroughly botanised a country as Great Britain, are almost daily adding to this enormous number. About one-fifth of the flowering plants belong to the great division of monocotyledons, or species with one seed-lobe and parallel-veined leaves (p. 49), while the remainder are dicotyledons, or species with two seed-lobes and netted-veined leaves.

The richness of any region in species depends very much on the climate, the character of the soil, and the varying contour of the surface, a region with a number of underlying formations being, as a rule, richer in species than one covered with a soil which only a few species affect, though the latter may be abundant in individuals, and the country, therefore, present an exuberance of vegetation which could not have been presaged from the mere list of the species found in it. In the tropics, for example, there is, to the eye, an amazing wealth of plant-life; yet an English meadow is really more bountifully supplied with flowers of varied hues than many an equatorial jungle. The heat and dampness of the tropics force the plants into foliage rather than into flower, and hence, in spite of the presence of many gorgeous forms and the sight of unaccustomed species, there is a monotony in the dense vegetation of such regions. The popular impression to the contrary is derived from the sight of conservatories, into which plants are collected from every warm region and placed side by side, though in Nature they might have grown thousands of miles apart. In like manner, the dense forest regions of the North—where, as in southern Norway and the north-west coast of America, the fir trees grow in thick masses down to the water's edge, rooting in every chink of the rock, until their roots are splashed by the sea spray—are poor in species, mile after mile being occupied by one or two kinds of trees, and by the dozen or fewer species of shrubs and flowering plants which find shelter under their unfriendly shade.

As a rule, however, the number of species though not necessarily of individuals, increases in a direct ratio according to the distance of the country from the Poles. Thus, while the North is poor in species, the South is—other circumstances being agreeable—rich. Hence, also Greenland and Spitzbergen have a sparse flora, and equatorial America, when not too dry, or too moist, or too covered with jungle, has a rich one. Scotland nourishes from 50 to 100 species of flowering plants on every square mile of its surface, while in the country around London—a district not in any

way remarkable for the wealth of its flora—there are about 400 species in the same area. This distribution is, in a country of about the same climate and other physical characteristics, very much the same. Take, for example, the flora of the Vienna district. This comprises 1,397 flowering plants and ferns, scattered over an area of 512 square miles. Yet, in Lower Austria (5,776 square miles), the entire flora consists of no more than 1,711 species, while the sum total of species growing in the Empire of Austria, including the old states of Lombardy and Venice (194,592 square miles), amounts to 4,450. If Lombardy and Venice are omitted, the deduction of their 13,700 square miles of area reduces the flora by no more than 73 species. Again, while Great Britain, according to the best botanical opinion,* has a flora numbering 1,488 flowering plants, Ireland increases the roll by only 20 species. As a specimen of the density of vegetation in other parts of the world, it may be mentioned that the old kingdom of Naples, not including Sicily, has a flora of 3,132 species, British India about 9,000, British Guiana 3,254, the Province of Bahia in Brazil 2,804, the Cape Colony 6,600, and the south-west of Australia 1,800 flowering plants. Dry regions, like the Atacama Desert (Fig. 258) and the Sinai Peninsula, have poor floras, the latter district containing no more than 260 species; while volcanic isles, which must necessarily derive their flora by migration from other islands, or from the mainland, are usually singularly poor in plant life. The modern floras have not, so far as richness is concerned, any relation to those which preceded them in Tertiary times, the climate of many regions having changed since that Period; while, in the course of ages, every flora has gained enormously by the migration of species from other areas in the manner already described (pp. 292–314). The presence or absence of certain animals has also a notable influence on their richness, for while some species, which require the aid of insects to fertilise them (Vol. I., pp. 11–14), cannot propagate themselves in districts where these insects are absent, others will, in the war with certain species, disappear (pp. 285–291). In general terms, it may be said that as the flora dwindles towards the North, genera diminish in proportion to species; and that the proportion of cryptogams to flowering plants decreases as the Equator is approached. The ratio which monocotyledons bear to dicotyledons is, in the Arctic regions, about 1 : 22; in temperate regions it is about 1 : 4; in the equatorial regions it is about 1 : 5. On dry mountain slopes the proportion decreases with the altitude, while moist slopes favour the increase of monocotyledons. On the other hand, while ferns in the plains of the great continents are to flowering plants in the proportion of 1 to 20, in the mountains of the same regions the ratio is as 1 to 7. In some warm islands they are—as in Jamaica—as 1 : 8, or as in Tahiti as 1 : 4, while in St. Helena and Ascension, the ferns are about half the flora, though, taking the entire temperate zone, the ratio of 1 : 70 would be about the proportion of ferns to flowering plants.

Grasses, sedges, and rushes, increase in proportion to other plants in accordance with the more northern latitudes attained. Thus, in the equatorial zones they are 1 : 11, in the temperate zone 1 : 8, while in Greenland the proportion is about 1 to 4.

Orders also, we have seen, even when widely distributed, vary much as to the number of species belonging to them found in different countries. Thus, of the Ranunculaceæ, about one-fifth are found in Europe, but only one-seventeenth in South America, and one twenty-fifth in India. Of 3,400 species of Leguminosæ, about 1,600 are found in the equatorial zone, about 1,300 north of it, and about 500 south of it. Again, of 9,030 Compositæ, 3,590 are natives of America,† 2,224 of Africa, 1,827 of Continental Asia, 1,042 of

* There must always be a difference of view as to what constitutes a "true" species, some botanists regarding the numerous varieties of hawk-weed, wild rose, and bramble as entitled to that distinction, while others reduce them to a few forms. Among writers on British plants Babington may be considered as representing the "hair-splitters," Bentham and Hooker the "lumpers."

† They are, however, poorly represented in the Brazilian forests.

Europe, and only 347 of the South Sea Islands. Of 1,849 plants collected in Sarawak, there were only six Compositæ. This poverty is in keeping with the general rule, that the tropical flora is characterised by the absence of herbaceous, and the predominance of arborescent types, which rarely shed their leaves.* Finally, not to weary the reader with details, it may be added that of 2,500 species of the spurge order (Euphorbiaceæ), three-eighths are found in equatorial America, and that of 216 species of Coniferæ, there are 165 in the Northern and 51 in the Southern Hemisphere. But, with the doubtful exception of some of the remoter Antarctic Islands, and spots in the sandy deserts of Africa and Asia, there are no parts of the globe without some vegetation. Even in the upper reaches of Smith's Sound, in the most northerly land reached by man, upwards of seventy species of flowering plants and ferns have been collected, while from Spitzbergen an even richer flora has been culled. Franz Joseph Land has a much scantier vegetation; but Greenland, with its 395 flowering plants, ferns, and fern-allies, deserves, in the heyday of summer and in favoured spots, the name which the shrewd Icelander applied to a region which a less enthusiastic explorer has termed the "Land of Desolation."†

CHAPTER XIX.

The Origin of the Floras of Different Regions.

Various Theories regarding the Points whence Plants have spread over the World—View of Single Areas for each Genus and Species now generally entertained—Dissevered Species—Bentham's Views on this Subject—Ancient Migration of Plants—The Migration of Species from Asia to America—The Old Idea of a Miocene Atlantis—Migration of Plants at the Glacial Period—The Alpine Flora—Its Nature and Origin—The Greenland Flora and its Bearing on this Theme—Hooker's Conclusions Opposed by Lange and Warming—The North as the Home of Early Floras—The Flora of Islands—Oceanic Islands—Their Characteristics—Continental Islands—Great Britain—Its Botanical Characteristics—The Origin of its Flora—Forbes' and Martins' Theories—Cultivated Plants—Impossibility of Tracing the Original Home of most of Them—Unger's Bromatorial Line—General Conclusions, etc.

Naturally, no subject in phyto-geography has given rise to more discussion than the question of how the different floras originated. (1), Linnæus thought that originally all plants were created on the sides of some lofty mountain in the Tropics, where vegetation could find, from base to summit, every kind of climate. However, this hypothesis will not explain the peopling of cold regions, nor how no plants of these regions are found in the intervening warm regions. (2), Buffon's idea was that all vegetation originated in the Arctic Regions, and spread, little by little, southward, modifying itself according to circumstances. (3), Then for a long period botanists held in great favour the doctrine of "specific centres of creation," the leading idea of this theory being that there were

* Bentham, *Journal of the Linnean Society* (Botany), Vol. XIII., pp. 484, 524, 546.

† Hooker, Appendix to Nares' "Voyage to the Polar Sea," Vol. II., pp. 301–326; Lange, "Meddelelser om Grönland," Vol. III.; Warming, *Ibid.*, Vol. XII.; Hart, "Botany of the British Polar Expedition of 1875–76" (*Journal of Botany*, 1880); Brown, "Florula Díscoana" (*Arctic Manual*, 1875), etc. With reference to Mr. Hart's remarks regarding the richness of the Disco flora, it may be well to note that only a small portion of my three months' stay in Disco Bay was devoted to botanical exploration, and that of this period, the smallest portion was spent on Disco Island. Moreover, while Mr. Hart was at Godhavn at the best botanical season, I spent only a few days there at a period when vegetation had all but disappeared.

throughout the world a number of points of special creation, having each a particular flora, by the great majority of naturalists, are at present entertained by very few. (4). The theory

Fig. 251.—SEMI-CULTIVATED GROUND IN THE ISLAND OF UALAN, CAROLINE GROUP. (*From Kittlitz.*)
On the left is seen a bread-fruit tree; in the middle are tree-ferns and taro plants; the tree in the right corner is a screw-pine; the plant with large leaves in the lower left corner is a Cyrtosp.

from which points the species which occupied the surrounding area spread in a radiating manner. These views, clung to at one time which is now espoused by the greater number of botanists is that "each species has been produced in *one* area alone, having subsequently

migrated from that area as far as its powers of migration and subsistence under past and present conditions permitted" (p. 351).

No doubt, there are many difficulties in explaining how the same species could have migrated to the widely different points at which it is found; nevertheless, these difficulties are continually being diminished, so that this theory seems to be the safest as well as the most philosophical which the botanist can adopt. "He who rejects it," Darwin declares, "rejects the *vera causa* of ordinary generation, with subsequent migration, and calls in the agency of a miracle." Edward Forbes often insisted that there is a striking parallelism in the laws of life through time and space. For instance, the endurance of each species and group of species is continuous in time, for the exceptions are so few that we may conclude that they are due to the fact of our not having yet discovered in any intermediate deposit the species which occur above and below. So, in space, it is the rule that the "area inhabited by a single species or by a group of species is continuous," the exception being accounted for by a former migrations under different conditions, or through occasional means of transport, or "by the species having become extinct in the intermediate tracts." *

Yet we must not be led away into supposing that in the space intervening between the two or more points where the same species was found land had invariably existed in former times, this idea having been carried to a dangerous extreme by Forbes and his school. There are natural and other causes daily in operation which will go far to account for much of the migration of species, without calling in the aid of catastrophes and cataclysms. Doubtless, also, changes of climate must have had their influence on migration. "A region, when its climate was different, may have been," Darwin suggests, "a high road for migration, but now be impassable." Changes in the level of land and in the contour of regions may have had much to do with allowing terrestrial species to migrate to localities where they can no longer go by similar means. This we may admit without believing, as Forbes insisted, that all the islands in the Atlantic must recently have been connected with Europe or Asia, and Europe, likewise, with America. Indeed, he will scarcely allow, if his doctrine is to be carried out to its legitimate conclusion, that a single island exists which has not recently been united to some continent or other. This we know not to have been the case, the oceanic Atlantic islands being, in some cases (Ascension, for example), of recent origin; while others, like Madeira and the Galapagos, have faunas and floras which show that they have been long isolated from the nearest continent.

Ancient Migrations of Plants.—There has, however, been a commingling of floras by a forced migration of species at periods long anterior to the present distribution of land and water, when the hysical geography of the world was different from what it is now. We know that in America, for instance, many of the existing plants are identical with the Miocene ones of Europe. Some species, like the oleander, have even maintained their existence down to the present time; for though the two floras have now widely differentiated, both belong to the same type. Unger † and Heer,‡ on botanical grounds alone, have advocated the existence of an Atlantic continent uniting Europe and America—"the Miocene Atlantis"—as explanatory of the relation of the Miocene flora of Central Europe with the existing flora of North America. This idea is, however, abandoned by nearly every naturalist, since the flora of the North Atlantic islands is now known to be different from that of Europe, which would scarcely have been the case if they had formed part of this supposed oceanic highway between Europe and America.§ Oliver,‖ on the other hand, is a supporter of the theory first

* "Origin of Species," p. 361.

† "Die Versunkene Insel Atlantis" (1853).

‡ "Flora Tertiaria Helvetiæ" (1855—1859).

§ This does not, however, preclude a land communication between Greenland and Europe during the Tertiary Age (pp. 208, 306).

‖ *Natural History Review*, 1862.

advanced by Asa Gray, that the migration of species, to which the community of types in the United States of North America and the Miocene flora of Europe is due, took place when there was an overland communication from America to Eastern Asia between the 50th and 60th parallels of latitude, or south of Behring Strait, following the Aleutian Islands. By this course they may have made their way, at any epoch—Miocene, Pliocene, or Pleistocene—antecedently to the Glacial Epoch, to Amoorland, on the east coast of Asia, and as Behring Strait is so narrow, they could have crossed in that direction by the action of the migratory forces at present in action.

Fig. 252.—WEST AFRICAN LANDSCAPE: EUPHORBIAS (SPURGES) AND BAOBABS (*Adansonia digitata*) IN THE VICINITY OF AMBRIZ, IN ANGOLA. (*From Monteiro.*)

It may be added that it has been noticed that races of plants have, in general, a greater tendency to migrate from east to west than from west to east, a fact which may possibly be connected with the earth's revolutions around its axis (Vol. I., p. 301).

Migration of Plants at the Glacial Period.—As far back as 1747 Gmelin noticed that on the tops of mountains, widely separated from each other, plants of the same species were found, and this he instanced as proof of separate creation. Indeed, the fact of species which could not well have migrated to these points so distant from each other being so found would be inexplicable, did we not know from irrefragable evidence that towards the close of the Tertiary Period, when the earth had a vegetation specifically the same as it now possesses, the northern and central parts of Europe, Asia, and America were subjected to a climate similar to that which at present prevails in the Polar Regions, and that icebergs and glaciers reigned supreme in lands where now—on their old moraines and by their ice-scratched rocks—flourish the vine and the olive (pp. 228–241).

This Glacial Period had a most important influence in imparting to the flora of the world its present distribution. As the cold period came on, the plants of the Arctic Regions would descend to lower latitudes, and those of more temperate zones be driven further and further southward until they met with some insurmountable obstacle, when

they would perish. As the ice began to disappear and the climate of the world again to resume its present character, these enforced *émigrés* would return northward, closely followed by the plants of more temperate regions. "And as the snow melted from the bases of the mountains the Arctic forms would seize on the cleared and thawed ground, always ascending as the warmth increased, and the snow still further disappeared higher and higher, whilst their brethren were pursuing their northern journey. Hence, when the warmth had fully returned, the same species which had lately lived together in a body on the European and North American lowlands would be found in the Arctic Regions of the Old and New Worlds, and isolated on many mountain summits far distant from each other, having been exterminated on all the lesser heights." This constitutes the *Alpine Flora.*

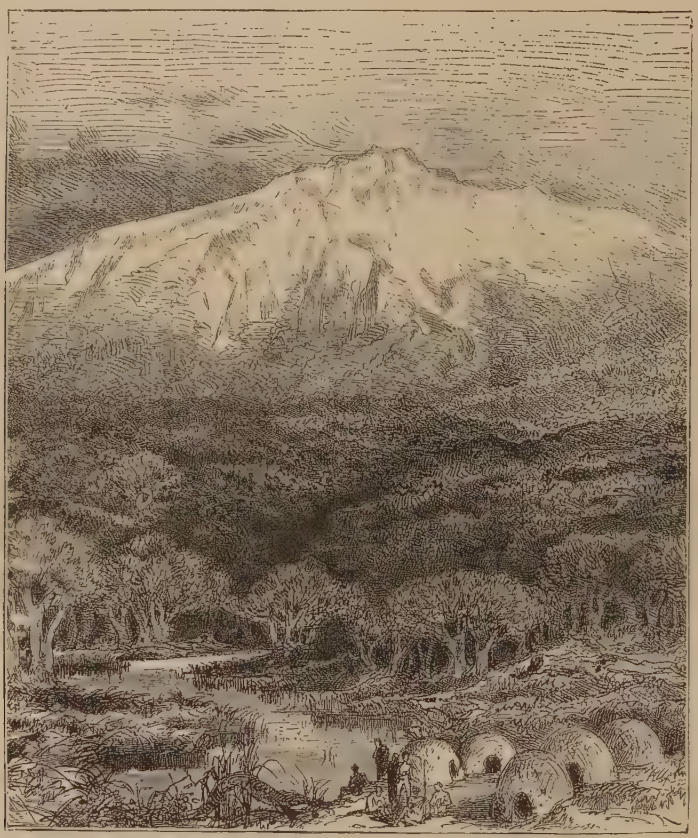


Fig. 253.—FOREST OF THE ANTARCTIC BEECH (*Fagus antarctica*) AND NATIVE FISHING VILLAGE IN TIERRA DEL FUEGO.

Thus, Mr. Darwin remarks, we can understand the identity of many plants at points so immensely remote as on the mountains of the United States and Europe. We can also understand the fact that the Alpine plants of each mountain range are more especially related to the Arctic forms living

due north or nearly due north of them; for the first migration when the cold came on, and the re-emigration on the returning warmth, would generally have been due north and south. Thus the Alpine plants of Scotland and the Pyrenees are more especially allied to the plants of northern Scandinavia, those of the United States to Labrador, and those of the Alpine peaks there are no signs whatever of glaciation.

On the other hand, there is now a remarkable uniformity of the plants of the whole circuit of the Arctic Regions, a uniformity dating before the commencement of the Glacial Period. At the present day the different portions of the Arctic Regions are

Fig. 254.—CHILI PINES (*Araucaria imbricata*).

those of the mountains of Siberia to the Arctic Regions of that country.

It is also probable that before this Glacial Period there was an ancient Alpine vegetation on the summits of the mountains, which, during the period of greatest cold, was driven down into the plains, and afterwards mingled with the new arrivals. For it is noted that though the plants of the great European mountain ranges are to a large extent identical, each range possesses some varieties or doubtful forms not found on the others. This belief is rendered still more tenable by the circumstance that on the summits of several separated from each other by wide gulfs and straits, and even by seas; and during the Glacial Period, when the inhabitants of the Old and New Worlds lived farther south than they do now, they must then have been even farther separated. Mr. Darwin attributes this to the fact that in the Pliocene Period, which preceded the Glacial, when some of the inhabitants of the world were specifically the same as now, the climate was warmer than at the present day. Hence we may suppose that the organisms which now live in lat. 60° N. during the Pliocene Period lived farther north under the Polar Circle,

in lat. 66°–67°, and that the present Arctic plants and animals then throve on the broken land nearer to the Pole. Now, if we look at a terrestrial globe, we see that under the Polar circle there is almost continuous land from Western Europe, through Siberia, to Eastern

Fig. 255.—AUSTRALIAN BOTTLE TREE (*Delabechea rupestris*).

America. And to this continuity of the circumpolar land, and to the consequent freedom under a more favourable climate for inter-migration, Mr. Darwin attributes to a considerable degree the uniformity in the sub-Arctic and northern temperate productions of the Old and New Worlds at a period anterior to the Glacial Epoch.*

* "Origin of Species," p. 333; Hooker, "Outlines of the Distribution of Arctic Plants" (*Transactions of the Linnean Society*, Vol. XXIII., p. 253).

This theory of Darwin's is highly probable, and explains many other hitherto inexplicable facts. For instance, through it we can understand the singular circumstance that the floras of Europe and America during the later Tertiary stages were more closely related to each other than at the present time; for during these warmer periods the northern parts of the Old and New Worlds must have been almost continuously united by land, serving as a bridge (p. 208), since rendered impassable by cold, for the inter-migration of their inhabitants.

Edward Forbes was the first who showed this influence of the Glacial sheet in driving plants to the southward, but Darwin and Hooker have demonstrated that not only were they driven into lowish latitudes, but even across the Tropics. At both Poles the same phenomenon seems to have occurred, though whether simultaneously or not we cannot as yet determine. Hooker has shown that between forty and fifty plants of the scanty flora of Tierra del Fuego are common to Europe, and on the Organ Mountains of Brazil some few European temperate, some Antarctic, and some Andean genera were found by Gardner which do not exist in the intervening hot countries. In Africa, ferns characteristic of Europe and the Cape occur on the Abyssinian Mountains; and Hooker tells us (p. 344) that plants found on the lofty island of Fernando Po and on the neighbouring Cameroons peak are closely related to those of the Abyssinian Mountains and of temperate Europe. On the Himalayas, and on the isolated ranges of India, Ceylon, and Java, and the Corean uplands, many plants occur identically the same or representing each other, and also representing plants of Europe not found in the intervening hot lands. Peculiar Australian forms are represented by plants growing on the summits of the mountains of Borneo. On the mountains of Victoria (Australia) Müller has discovered several European forms; many plants of European genera are found in Australia, though not in the intermediate torrid zones; and similar instances could be multiplied from New Zealand and elsewhere. In brief, as

Hooker puts it, "the Scandinavian flora"—which comprises the bulk of the European Arctic plants—"is present in every latitude of the globe, and is the only one that is so." The same is true of marine productions. On Hooker's authority, it is stated that twenty-five species of Algæ are common to New Zealand and to Europe, but have not been found in the intermediate tropical seas.

The Northern forms found on the mountain

Fig. 256.—THE MORICHE OR ITA PALM OF TROPICAL AMERICA (*Mauritia flexuosa*).

(*From a Sketch by Louis Agassiz.*)*

* This palm covers large tracts in the Delta of the Orinoco, which are frequented by the Guarani Indians. These tribesmen subsist almost entirely on the produce of the *Mauritia*, and when the swamps are inundated sling their hammocks between the tops of the trees protruding above the surface of the water. From the leaves cord is made; the fermented juice yields palm wine; the fruits form the raw material of another beverage; while a sago-like substance is extracted from the centre of the stem. It is common also on the Amazon and Rio Negro.

ranges of tropical regions are, as might be expected, not Arctic, but temperate species. From this it can be readily conceived how the balance of vegetation must have been disturbed, and how great an influence the Glacial Period must have had in commingling and giving a character to floras. Though, doubtless, there was a migration towards the Tropics from both north and south, the northern migration preponderated. It is impossible to canvass all the facts and arguments which have been adduced in favour of this view, but, at all events, it seems settled that during this Glacial Period the plants of the colder regions were driven into every latitude, and, returning north, brought some of the plants of the countries they visited with them, and that to this northward retreat is due the Alpine flora, which took refuge from the heat on the mountain tops, for "a mountain is an island on the land." In the eloquent words of Darwin, "The living waters have flowed during one period from the north and during another from the south, and in both cases have reached the Equator: but the stream of life has flowed with greater force from the north than in the opposite direction, and has consequently more freely inundated the south. As the tide leaves its drift in horizontal lines, though rising higher on the shores when the tide rises highest, so have the living waters left their living drift on our mountain summits in a line gently rising from the Arctic lowlands to a great altitude under the Equator. The various beings thus left stranded may be compared with savage races of men, driven up and surviving in the mountain fastnesses of almost every land, which serve as a record, full of interest to us, of the former inhabitants of the surrounding lowlands."

The theory thus stated in the briefest outline has obtained the general acceptance of botanists, simply because it explains the greatest number of facts in the most reasonable manner, without making too heavy a draft on our imagination. Still, there are many puzzles connected with the nature of the Arctic-Alpine Flora which may never be explained, and the solution of which is none the less difficult, owing to the absence of the remains of the earlier Alpine species. Hence, the views mentioned have not passed without cavil. Mr. Ball, for instance, whose acquaintance with mountain plants is, perhaps, unequalled, is convinced that most of the Alpine flora is of an older date than the Glacial Period, and that, though some of the species—of which only a small percentage is common to the Arctic Regions, where the conditions of life are, in many respects, widely different from those which obtain on the tops of high mountains further south—may be due to the migration of that Epoch, its effects "both on the distribution of plants and in the climate of Europe have been greatly overrated." The highest ridges of the Alps, even during the period of maximum cold, were not completely covered with ice and snow, while the richest flora is found on the oldest summits—on those which have been longest above the surface of the sea. There are many species, and at least four generic types, peculiar to the Alps. Among these is *Wulfenia* (p. 351), one species of which inhabits a secluded corner of the Alps, another is found in Northern Styria, while a third allied species has its home in the Himalayas. Finally, Mr. Ball is perhaps alone in believing that the migration of this flora northward began long before the Glacial Period.*

If, however, Sir Joseph Hooker's views regarding the nature of the Arctic-Alpine Flora have as a whole held their ground, the conclusions he came to regarding the nature of important sections of it have not been quite so successful. Greenland, for example, Hooker affirmed to be more European than American in its flora, Davis Strait forming a biological line of separation between it and the New World proper. This view was, until lately, very generally accepted: among others, it was advocated by the present writer. Professor Lange of Copenhagen has, however, from a fuller analysis of its flora, contested this conclusion, by endeavouring to prove

* Ball, "On the Origin of the Flora of the European Alps" (*Proceedings of the R. G. S.*, 1879, pp. 564–588).

Fig. 257.—LANDSCAPE, WITH BAMBOOS, NEAR ARIMA, IN THE ISLAND OF TRINIDAD.

that, botanically, Greenland is a part of America, Denmark Strait between it and Iceland, and not Davis Strait, being the water line dividing the floras of the Old and New Worlds.*

In like manner, Professor Warming has made an attempt to show that the commonly-accepted theory of the immigration of plants from the south to Greenland at the close of the Glacial Period is superfluous, in so far that the Greenland flora is essentially Arctic, and might have survived on the summits of the mountains all through the Great Ice Age. Some of the mountain peaks—such as the Nunataks of Jensen (Vol. I., p. 374)—still peering above the great interior ice, bear no marks of having been glaciated, and still support a comparatively luxuriant flora. Nor does this eminent botanist consider that the theory of the Shetlands, Faroe Islands, and Iceland, having been the remains of a land bridge by which the Scandinavian plants passed northward, is any better proved, even were such a terrestrial communication necessary on the theory which he has espoused, in opposition to that first suggested by the present writer, and since then supported by James Geikie, Blytt, Nathorst, Drude, and others.† Space will not permit of this ingenious doctrine being fully discussed. Nor is this the place for any such analysis; it is, however, only just to my distinguished friends that their objections to the current opinions should be stated.‡

However, whatever difference of opinion may exist regarding the nature and origin of the Greenland flora, there is gathering an ever-increasing volume of conviction that when Buffon suggested the North as the home of vegetation, he was more correct than he himself suspected, or than the world has, until lately, given him credit for being. If, as is almost universally admitted, the globe before the deposition of any sedimentary rocks was a hot ball (p. 269), then the Polar Regions being the earliest to cool would naturally be the first to attain a temperature under which vegetation could exist. De Saporta, for example, points to the fact that the richest fossiliferous rocks are in as high latitudes as 60°, and that as far back as Silurian times there was life of a tropical character not many degrees from the North Pole (p. 68). Dawson has suggested that the oldest American vegetation must be looked for to the north of Newfoundland. In the Polar Regions also, down to the Tertiary Period, flourished a succession of luxuriant floras, the modern representatives of which must be sought in much more southerly latitudes (pp. 203–216). To the Northern Miocene forests Gray traces the temperate woods of modern America. The Carboniferous vegetation was most profuse in the Northern Hemisphere, while in the Oolitic Age Europe possessed cycads, screw pines, and araucarias, now either confined to or dominant in the Southern

* Lange: Studier til Grönlands Flora" (*Botanisk Tidsskrift*, 1880, Bd. 12, pp. 132–157), and "Conspectus floræ groenlandicæ" (1880 and 1887).

† This land communication between Greenland and Europe might be abandoned if its postulation depended on the nature of the flora alone. But without it, there is no explaining either the arrival or the retreat of the American musk "ox" (p. 238) at and from Europe at the close of the Glacial Period. The difference in the geological structure of Greenland and of the North Sea Isles is no argument whatever against the theory mentioned. Moreover, as many of the Greenland plants and animals cannot now exist on the tops of the southern mountains of that country, it is extremely unlikely that, either on Sir Joseph Hooker's or Dr. Warming's theories, they could have survived the Glacial Period in South Greenland; if even we did not know from an examination of the country that all the lowlands now bare of ice, up to a very considerable altitude, had, during that Age, been overwhelmed by the great glacial mass, which has not yet disappeared from the interior of the country.

‡ Warming: "Om Grönlands Vegetation" (*Meddelelser om Grönland*, Hefte XII., 1888), a work so exhaustive that it leaves almost nothing unsaid; "Beretning om den botaniske Expedition med *Fylla* in 1884" (*Ibid.*, Hefte VIII., pp. 175–201); "Tabellarisk oversigt over Grönlands, Islands, og Færöernes Flora" (*Vidensk. Meddelelser fra den naturhistoriske Forening*, 1887, pp. 1—58), and "Neuere Beiträge zu Grönlands Flora" (Engler's *Botanische Jahrbücher*, Bd. IX., pp. 274—279); Blytt, *Ibid.*, 1882, pp. 1—50; Nathorst, *Öfversigt af Kongl. Vetenskap. Akad. Förhand. Stockholm*, 1883 and 1884, and "Polarforskningens bidrag till forntidens växtgeografi (Nordenskjöld's *Studier och forskningar*, 1884); Drude, "Pflanzengeographische Anhaltspunkte für das Bestehen einer Landbrücke zwischen Grönland und West-Europa zur Eiszeit" (*Das Ausland*, 1883, p. 325), etc., etc.

Hemisphere; while similar facts might be culled from what we know of the history of the Cretaceous plants and animals. Up to this period there was a greater uniformity of climate, and therefore of life, over the globe than subsequently obtained. Then a marked distinction between temperate and tropical vegetation began, until, in the Eocene Age, we notice this in a notable manner. As the tropical flora settled down into its own area, the Miocene vegetation took possession of the present temperate zones of the Northern Hemisphere, while the differentiations which then gradually arose furnished the Mediterranean and Mexican Regions with their characteristic floras.* The advent of the Glacial Period caused another and equally notable change, the nature of which has just been described.

All along, the migration was from north to south. There has been, as Hooker so forcibly describes the phenomena, a continuous current of vegetation from Scandinavia to Tasmania, New Zealand, and even the Antarctic Islands, many of the species remaining unchanged throughout. "It matters not what the vegetation of the bases and flanks of these mountains"—of the south—"may be; the northern species may be associated with Alpine forms of Germanic, Siberian, Oriental, Chinese, American, Malayan, and finally Australian and Antarctic types; but whereas these are all, more or less, local assemblages, the Scandinavian asserts his prerogative of ubiquity from Britain to beyond its antipodes."† Yet there is no reciprocity; in spite of the many northern forms which have reached the south, not one Australian plant has entered any part of the North Temperate Zone, except, of course, through man's agency, within the past century, and the same may be said of the typical southern vegetation generally, whether developed in the Antarctic lands, New Zealand, South America, or South Africa. A few Antarctic genera found in the Bornean Alps, a species of Acæna‡ in California, a Casuarina (Fig. 210), and three species of Stylidium in Ceylon and India, and three other genera (two of them orchids), found in China and the Philippines, are the other representatives of the Australian flora which have extended to the north, though in not one instance are the species the same. This curious fact is mainly due to the different distributions of land and water in the two hemispheres—the North having the maximum of land surface, the South the minimum, this rendering it more easy for species to migrate from the one hemisphere than from the other, where there is less continuity of the terrestrial area.§

Island Floras.—Some of the most instructive facts in relation to phyto-geography are afforded by the study of the Flora of Islands. The flora of islands lying close to a continent is generally identical with that of the nearest mainland, though frequently poorer in species than the same space of the neighbouring continent; but if the islands lie at a distance from any mainland, a very curious relationship without identity is observed in their flora.

The species of plants which inhabit islands are few in number compared with equal continental areas. For example, New Zealand, with the outlying islands of Auckland, Campbell, and Chatham, notwithstanding its diversity of physical features, has less than 1,000 species of flowering plants, of which, however, nearly three-fourths are endemic or peculiar.

* Dyer, *Proceedings of the Royal Geographical Society*, 1878, p. 443; Asa Gray, *Address to the American Association for the Advancement of Science*, 1872, and "Forest Geography and Archæology" (*American Journal of Science*, 1878); Hooker, *Presidential Address to the Royal Society*, 1878; Saporta: "L'Ancienne Végétation Polaire" (1877); Clodd: "Story of Creation" (1888), p. 146; Dawson: "Geological History of Plants" (1888), p. 237, etc.

† Introductory essay *On the Flora of Australia*, p. 103. In the Miocene beds of Tasmania Mr. Johnston tells us that trees of European genera abound, and Ettingshausen makes a similar statement respecting the Tertiary flora of Australia and New Zealand.

‡ *Acæna ovina* is a common weed in South Australia and Tasmania, where the bristles of the fruit getting entangled in the fleeces of the sheep, gave great trouble to the wool-grower (p. 302). Housewives know it from adhering to drying linen, and every traveller must remember the bur-like fruit which clung to his clothes while walking through the Antipodean bush. *A. Sanguisorba* is the "Piri-Piri" of the Maoris of New Zealand, who value a decoction of its leaves as a medicine.

§ Wallace: "Island Life," p. 495.

Now, compare this with an equal area of Australia and the Cape of Good Hope, and we must see that some other influence must be at work. Even within a circuit of twenty miles of Edinburgh there are 969 species and 61 varieties of flowering plants and ferns; in the county of Cambridge 847, and in the Isle of Anglesea 764; but even after making allowance for a

Fig. 258.—"QUISCO," THE CACTUS OF THE ATACAMA DESERT, IN PERU. (*Cereus atacamensis*).

few doubtful natives and the more minute search those long botanised localities have obtained, the difference is sufficiently remarkable. The Island of Ascension has only about half a dozen flowering plants which can be termed endemic, and the introduced ones in St. Helena have in many cases destroyed the native (p. 297), so that, on the doctrine of the distinct creation of each species, Mr. Darwin argues, we would require to admit "that a sufficient number of the best adapted plants and animals were not created on oceanic islands; for man has unintentionally stocked them from various sources far more fully and perfectly than did Nature." Though the number of the inhabitants of oceanic islands is scanty, yet there are often, as in the flora of the Galapagos, many endemic species.

Another curious observation is that some islands have endemic plants with hooked seeds and yet no mammals, so that on the theory of these hooks being specially intended to propagate the seed by attaching it to the hide of animals this is puzzling. Darwin, however, considers that on his theory this presents no difficulty, for a hooked seed might be transported to an island by some other means; and the plant springing from it afterwards becomes slightly modified, but still retaining its hooked seeds. It would then form an endemic species, having as useless an appendage as any rudimentary organ —for instance, as the shrivelled wings under the soldered wing-cases of many island-inhabiting beetles. Oceanic islands also often possess trees or bushes belonging to orders which elsewhere include only herbaceous plants, a curious fact, when we know that, according to the analysis of De Candolle, trees from whatever cause have generally confined ranges. Darwin, however, attempts to explain this anomaly by showing that trees would, according to De Candolle's view, have little chance to reach distant oceanic islands, but that an herbaceous plant, which in the struggle for existence on the mainland might continue lowly, when it reached the comparatively unoccupied solitudes of an island where it would have to compete with herbaceous plants only, ought, in course of time, to reach the size of a tree or shrub. Various plants we know are in some places scarcely more than herbaceous; in others, more favourable to their growth, bushes; while in a third situation best adapted to their constitution, they will attain the height of trees.

Islands, we have seen (Vol. I., p. 31), are divisible into two great groups, (1) *Oceanic* and (2) *Continental*. The Oceanic Islands are usually volcanic or coral, and are peopled in accordance with their relations to the

neighbouring continent, their distance from it, or the nature of the currents, the winds, etc., bearing to it the seeds of plants; while the Continental are to all intents only dissevered portions of the continent off which they lie.

Floras of Oceanic Islands.—The flora of oceanic islands shows a remarkable affinity to that of the nearest mainland without being actually identical. For example, the Galapagos Islands are between five and six hundred miles distant from the nearest point of South America. Here every plant and animal bears the unmistakable American stamp, though almost peculiar to the islands. Yet they have no relation in the conditions of life, in the soil, in the height of the land, or in climate, to the American Continent. On the contrary, in these respects the Galapagos are nearer related to the Cape Verde Islands, the products of which have no connection whatever with those of the Galapagos or of South America, but find their nearest connection in Africa. Why, therefore, should the Galapagos possess species endemic and yet so closely related to though not identical with those of America? "Facts such as these," Mr. Darwin answers, "admit of no sort of explanation on the ordinary view of independent creation; whereas, on the view here maintained, it is obvious that the Galapagos Islands would be likely to receive colonists from America, whether by occasional means of transport or (though I do not believe in this doctrine) by formerly continuous land and the Cape de Verde Islands from Africa; such colonists would be liable to modification, the principle of inheritance still betraying their original birthplace."

The rule, indeed, that the endemic productions of oceanic islands are related to those of the nearest continent or of other near islands is almost universal. There are, however, a few exceptions which can be explained without much difficulty. Kerguelen Island is closest to Africa geographically, but yet it has American products; but it is held that the theory of its having been originally stocked with plants brought in earth, etc., on icebergs, and field-ice, from America, accounts for the anomaly. We confess that the iceberg theory is not very satisfactory (p. 310), but in lieu of any other explanation at all reasonable and agreeable to our knowledge of the operations of Nature, it is worthy of respect until a better is suggested.

The Flora of New Zealand, again, is related

Fig. 259.—THE BRAZILIAN ARAUCARIA (*A. brasiliensis*).

to Australia—the nearest continent; but on the other hand it is also related to that of South America, which is enormously remote. This relationship has been unsatisfactorily explained by the hypothesis of both countries (New Zealand and South America), having been originally peopled from a great Antarctic continent, which either now no longer exists, or exists in the fragments of the Antarctic Islands, in the New South Shetlands, etc., and that in those days the climate was different from what it is now.

This solution of the problem must, however, be accepted, unless we are to prefer Mr. Wallace's theory, supported by geological facts,

that there was a union between New Zealand and Australia, in the latter part of the Secondary Epoch at a time when Eastern Australia was widely separated from Western Australia. The relationship of the Floras of South-West Australia and the Cape of Good Hope, as well as of New Zealand to South

Fig. 260.—THE SOUTH AMERICAN FIG ("FIGUEIRA").

America, may be explained on the hypothesis that the forms common to these regions are those which once lived in the north, and were driven south—as we know they were—by the presence of other floras, and now feebly survive in the localities where they are found.

The various islands in the Galapagos Archipelago, though different in their floras, are yet infinitely more closely related to each other than to the neighbouring mainland or to the inhabitants of any other part of the world, and on Christmas Island, owing to its comparatively brief isolation, the plants, though not different from those of the nearest mainland, are yet beginning to alter.

Perhaps, in connection with the peopling of oceanic islands, it is well to briefly mention two other laws of phyto-geography not hitherto touched on, namely:—(1), The lower any group of organisms is, the more widely it is apt to range—a fact perhaps due to their seeds being minute, and therefore well fitted for transportation. (2), Some of the species of widely-ranging genera themselves range widely. Even a narrow arm of the sea, if of ancient date, will often isolate an island from the mainland, or one island from another, as completely as if hundreds of miles of water rolled between them. Not to instance more examples, we may mention the remarkable division of the fauna, and to a certain

extent of the flora, of the Malay Archipelago as pointed out by Mr. Wallace. Here there are two great types of life widely distinct the one from the other, namely, the Indo-Malayan and the Australian, and the line of division between them is not determined by any diversity of climate or soil, or by any recent separation by means of some wide gulf interposed between them, but simply by the deep channel separating the islands of Bali and Lombok, this fact indicating that at this point there has been a lengthened separation of two continents, and their corresponding faunas and floras.* This brings us to speak of continental islands.

Floras of Continental Islands. — When islands are so close to any great continent that they may botanically be considered a part of it, their disseverance from the larger area being geologically recent, their flora rarely presents any marked endemic species, but is, to all intents and purposes, identical with that of the nearest mainland. The British group afford a good type of these continental islands. Their flora consists of about 1,500 flowering and fern plants, and upwards of 3,000 species of the lower cryptogami or flowerless species. Yet, with the exception of a few unimportant local varieties and some minute cryptogamic species, there are only two species of plants found in these islands which are not also got on the Continent. These are the pipewort (*Eriocaulon septangulare*), an American species, which we have already taken note of when discussing the work of currents in dispersing plants over the world (p. 308), and *Spiranthes cernua*, an American orchid related to the British "Lady's Tresses," but unknown on the eastern side of the Atlantic, except in a single bog at Berehaven, near Castletown, in Ireland. Yet on a small island like Madeira, out of about 720 plants, there are 100 species and marked varieties peculiar to it, the island being an oceanic one.

Though enjoying a mild and, on the whole, equable climate, the flora of Great Britain is by no means uniform, but consists of fragments of several floras, contributions from the neighbouring lands at a period when the British Islands had not ceased to be a part of the Continent of Europe. The entire absence of endemic species—except in critical genera, like *Rubus* (bramble), *Hieracium* (hawkweed), and *Rosa* (rose), the forms of which admit of a wide difference of opinion—and the way the native plants are distributed, also point clearly to the conclusion that Britain was peopled with its vegetable inhabitants long before sea and land acquired their present relations.

The recognition of this fact is due to the labours of Cottrell Watson,† Edward Forbes,‡ and Charles Martins.§ The two latter botanists have attempted to trace the origin of these floras, and all three essentially agree in what the floras consist of, though differing in their sub-divisions and, to some extent, in their nomenclature, while they are distinctly in different camps regarding the causes which have led to the vegetable colonisation of the islands. The arrangement of M. Martins is, perhaps, the simplest and best. He divides the flora of Great Britain and Ireland into four types, as follows:—

(1), The *Asturian* type, which obtains in Ireland, and is the remains of a Peninsular Flora. In the south-west of Ireland there are about a dozen plants natives of the Asturias, in Spain, and which do not exist even in the eastern counties of Ireland. Among these may be mentioned the strawberry tree of the Killarney Lakes (*Arbutus Unedo*), the fringed rock cress (*Arabis ciliata*), the pale butterwort (*Pinguicula lusitanica*), the London Pride (*Saxifraga umbrosa*), the kidney saxifrage (*Saxifraga Geum*), St. Dabeoc's heath (*Menziesia polifolia*), the curious

* Wallace, *Journal of the Royal Geographical Society*, Vol. XXXIII., p. 217, and "Malay Archipelago," p. 14.

† "Compendium of the Cybele Britannica" (1870–72), and "Topographical Botany" (new edition, by J. G. Baker and W. W. Newbould, 1883), which contain the latest statements of Mr. Watson's views, and the only ones which he wished to be quoted, though the questions at issue were mooted by him as early as 1835.

‡ *Memoirs of the Geological Survey of Great Britain*, Vol. I. (1846), p. 336.

§ *Smithsonian Institution Report*, 1858, pp. 229–237

variety of the cross-leaved heath known as *Erica mackaiana*, and the lovely bristle fern, *Trichomanes radicans*, which, however, has also been found on the Snowdon Range and south-west of England (Devonshire and Cornwall), and the south-east of Ireland (Cork and Waterford), presents a close relationship to the flora of Brittany and Normandy. The

Fig. 261.—THE TRAVELLERS' TREE OF MADAGASCAR.
(*Urania speciosa*).*

on the Isle of Arran, though in the latter locality it is a very questionable native.

(2), *The Armorican Type*, limited to the Cornish heaths (*Erica ciliaris* and *E. vagans*), *Sibthorpia europæa* (also found in the Channel Islands), and the purple spurge (*Euphorbia Peplis*), are examples of this type.

* This noble palm-like tree (sometimes described as *Ravenala madagascariensis*) belongs to the Banana Order (*Musaceæ*), and forms a striking feature in the scenery of Madagascar. It obtains its popular name owing to travellers cutting its leaf stalks in order to slake their thirst on the abundant juice which exudes. A dye is extracted from the capsules.

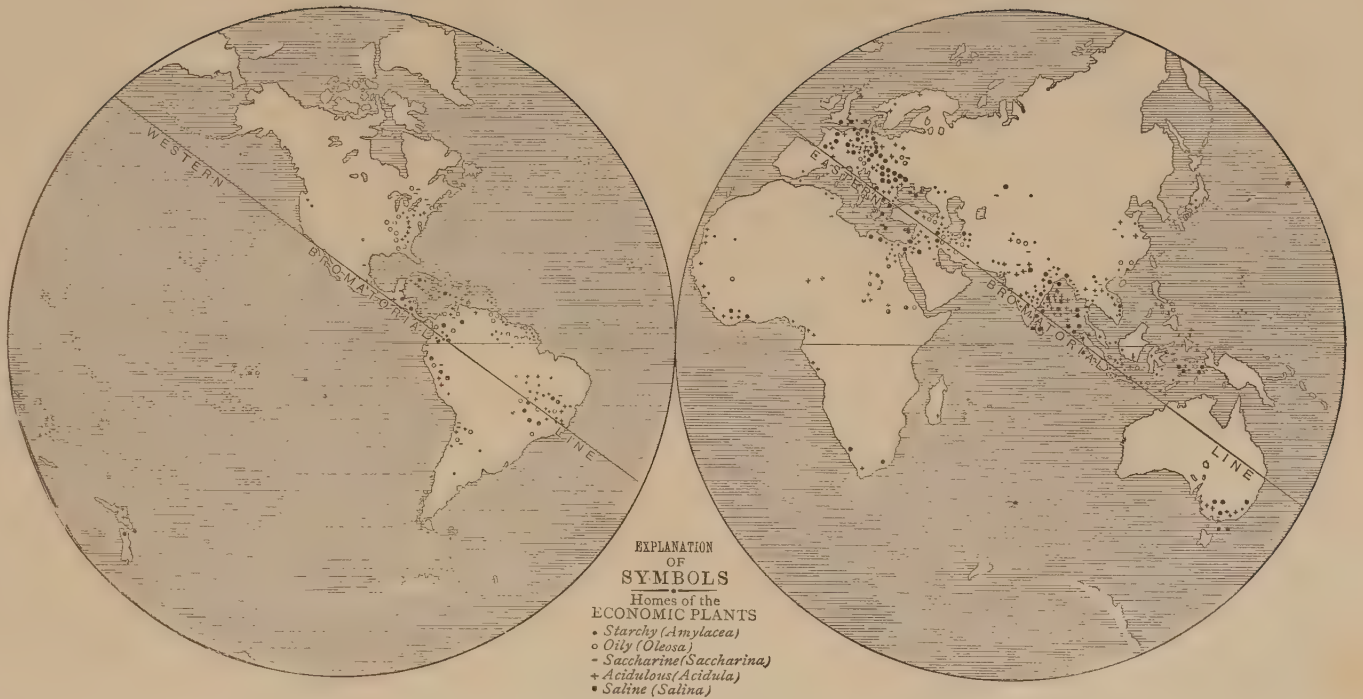


Fig. 262.—THE BROMATORIAL LINE. *(After Unger.)*

(3), *The Boreal or Alpine Type*, confined to the mountains of Scotland, Cumberland, and Wales, analogous to that of the Alps and the Arctic Regions, where it descends to the level of the sea (p. 360). It contains, however, many species which have never yet been recognised in the Swiss Alps, though most of them are found there and in the far north. The dwarf willow (*Salix herbacea*), the trailing azalea (*Loiseleuria procumbens*), the black bearberry (*Arctostaphylos alpina*), the water awlwort (*Subularia aquatica*), many saxifrages, such as *Saxifraga Hirculus, S. oppositifolia, S. aizoides, S. cæspitosa, S. cernua, S. rivularis*, and *S. nivalis*; the two species of Oxytrope—the yellow (*Oxytropis campestris*) and the purple (*O. uralensis*), the Alpine astragal (*Astragalus alpinus*), etc.

(4), *The Germanic Type.*—This is the predominating flora of Great Britain, and is so much the basis of the vegetation that it is sometimes styled by English botanists the "British type." It is the flora of the north of France and Central Europe. The most familiar examples are the daisy (*Bellis perennis*), the heather (*Calluna vulgaris*), the hazel (*Corylus Avellana*), and other generally distributed species. The marine vegetation (p 346) arranges itself into districts not very widely dissimilar.*

Forbes' Theory of the Origin of the British Flora.—It is to Edward Forbes that we are indebted for the most plausible explanation of the origin of this flora. Though he utilised the materials accumulated by Mr. Watson—who never adopted any portion of the new theory, preferring to look to climate as the leading agent in the distribution of the British flora—it was he who first made this bold foray into a new region, pointing out the way to others, who have, since his day, worked other fields than those in which he first broke ground. His theory, essentially, was that these islands have been colonised by several successive acquisitions from Continental Europe, from the Tertiary Period to our own. When a vast continent stretched from the Mediterranean Regions to the British Islands, the plants of the Asturias and of Brittany (Armorica) peopled the south of England and Ireland (p. 226). To that period succeeded the Glacial Epoch, during which the land was submerged to the depth of about 1,500 feet. This was the epoch of the migration of those Arctic plants which still inhabit the summit of the Scottish mountains. When the land emerged anew, England was united to France, and the temperature was what we now find it (Fig. 170, p. 240). At that time the great Germanic invasion took place, displacing to a large extent all the others, and leaving but scattered vestiges of their existence. Thus, while the Asturian plants were reduced to a few species, confined almost wholly to the south-west of Ireland, the robust progeny of the north finished their conquest and possessed themselves of the soil. This colonisation completed, England was separated from the Continent: so that a geological incident, insignificant in comparison with those which preceded it, has exercised an immense influence, not only on the political destinies, but on the flora and fauna of the country. All of this theory is based upon more or less well-established geological facts (pp. 228–241).

Martins' Theory.—M. Martins, while studying the British flora from the same premisses as Forbes, has arrived at a different explanation. He asks, did the British vegetable colonies come from Europe or America? A considerable number of plants being common to both, the question presented some difficulties. He found, however, more than one hundred species exclusively European; all the others were common to Europe and America. "Europe, then, must have had the

* Mr. Watson recognises six types of distribution among the British land plants. (1), The British type-species, widely spread through south, middle, and northern Britain; (2), the English type-species, chiefly seen in south or south-middle Britain; (3), the Scottish type-species, chiefly seen in north or north-middle Britain; (4), the Highland type-species, chiefly seen about the mountains; (5), the Germanic type-species, chiefly seen in east England; (6), the Atlantic type-species, chiefly seen in west England. These types of distribution are not, however, separated by any divided lines and, perhaps, for our purpose the less minute classification of M. Martins is preferable.

greater share in the colonisation of these archipelagoes; a great vegetable migration had advanced across England and Scotland, the Orkney, Shetland, and Faroe Islands, as far as Iceland. Some species had come directly from the coast of Norway. But in the meantime, in an opposite direction, the Arctic plants had propagated themselves across Iceland, Faroe, and Shetland, to the mountains of Scotland, where they found a second home. This double migration is evident from the proportional number of the different plants; for if we calculate that of exclusively European plants which enter into the flora of Shetland, we find but $\frac{1}{4}$, that of Faroe but $\frac{1}{5}$, and finally that of Iceland but $\frac{1}{10}$. Thus, as we leave Europe behind us, the number of plants of its peculiar growth proportionally diminishes; but at the same time, that of the plants of Arctic origin increases in nearly an inverse ratio." M. Martins, while agreeing with Forbes as to the colonisation of the British Islands, hesitates in adopting his bold hypothesis, and thinks that all the peculiar facts regarding the distribution of British plants may be explained without resorting to geological revolutions. The prime agents in disseminating the materials of the British Flora are, from his point of view, the Gulf Stream, which has wafted to British shores the seeds of the New World (p. 208), and may have scattered some of those shed by the native species along the Northern coasts laved by it—and the winds which carry light bodies great distances (Vol. I., p. 145), and birds of passage in their spring and autumn flights.*

This outline of Martins' theory is given, not that it is at all satisfactory, but simply to point out the weak points of the rival one, for though the agents he adduced in support of the vegetable peopling of Great Britain have had their share in bringing about the present state of matters, yet of themselves they are quite insufficient to do so, and will not explain all the peculiarities of the flora. Unfortunately also for M. Martins' theory the fauna has also to be explained, and the facts adduced by him in no way account for this.

The main difficulty in accepting Forbes' views in full is that knowledge obtained since he wrote has rendered it doubtful whether the Asturian or even the Armorican floras could have survived the Ice Age in Britain, or the submergence which followed it. The Asturian saxifrages and heaths of the west and south-west of Ireland grow on glaciated mountains and in valleys abounding with moraines.† The Alpine flora could, however, have easily survived the Glacial Period, and the other floras may have entered the British area at the close of the Arctic conditions which had hitherto prevailed. But the broad fact remains that the flora of Britain dates from a period antecedent to the present distribution of land and water, though the meagreness of the islands in plants and animals compared with the Continent may be due to the fact of the connection with that great area being cut off before the migration westward had been completed. To this cause, also (p. 240), the comparative botanical and zoological poverty of Ireland must be traced.‡

Cultivated Plants.—Now and then we introduce a new plant into cultivation, when, of course, it becomes acclimatised, or naturalised. But the origin of vast numbers of the cultivated plants of all countries dates from a time far prior to ours; is lost, indeed, in the mists of antiquity. There are few, the beginning of which can be traced from wild plants, and even then their supposed progenitors are commonly found in the vicinity of inhabited places, so that a suspicion remains that the supposed ancestor of the cultivated one may be only a degenerated field or garden plant. Man has, however, so entirely changed the

* On the influence of winds, currents, and birds, on the Greenland Flora, the reader is referred to Prof. Warming's remarks in *Meddelelser om Grönland*, Bd. XII., pp. 203–215.

† James Geikie: "Prehistoric Europe," pp. 508–533, in which the question is discussed from a geological point of view. Professor Geikie is, however, not quite accurate in the conclusions he has arrived at regarding the Greenland Flora.

‡ In addition to the works quoted, particularly Mr. Wallace's "Island Life" (1880), the Lecture on Island Floras by Sir Joseph Hooker (*Gardeners' Chronicle*, January, 1867), and Mr. Hemsley's Botany of the *Challenger* Expedition (1885–87), may be consulted for fuller details on the subject of Insular Floras.

character of the plants by cultivation—by forcing their growth within a certain limited time, by cutting them down instead of allowing them to shed their seeds, by taking them indoors at the approach of winter, by selecting the best varieties, and by a hundred other devices—that it would be an idle task in the great majority of cases to identify the domesticated species with the wild ones, even could they be found. It is probable that from the earliest dawn of the rudest civilisation, man reared grains and other plants. The inhabitants of the Swiss Lake Dwellings, we know from the charred remains in mud around their houses, cultivated some kinds of cereals (pp. 260, 298), and when America was discovered the Indians were planting the maize. The oldest records of the Hindoos and Chinese represent them as growing rice; and in the oldest Hebrew books the juice of the vine is mentioned as making glad the heart of man.* But written and traditional history is only the most minute fragment of the story of our race. At all events, like the domesticated animals, the cultivated plants are of a very remote antiquity.

If, however, the distribution of the plants yielding the chief food products is studied, it will be found that they cluster, to a large extent, on each side of a line which Unger has termed the *bromatorial* (Fig. 262), and that the greater number of them are in the warmer regions of the Old World. Taking 770 nutritious species yielding notable amylaceous (starch-bearing), oily, saccharine, acidulous, or saline products, Unger found that 566 belong to the Old, 204 to the New World. The tropical zone is rich in these alimentary plants. In the Southern Hemisphere there are comparatively few, and in Australia so much is this the case that explorers perishing of hunger in the interior of that island continent have found no other plant than the "Nardoo"—the spores and seed cases of *Marsilea macrocarpus*, a fern-like plant—on which to subsist. In the Northern Hemisphere the western portion is poorer in useful plants than the eastern portion, so that we may draw a line from the Moluccas to Ireland, round which will cluster the most important cultivated plants whose homes are in the East India Archipelago, in Further India and Hindostan, in Persia, Armenia, in the Caucasus, the Crimea, Greece, and Central Europe. This Bromatorial Line is found to extend through America, by way of Brazil and Peru, to Guiana, Ecuador, Central America, the West Indies, and Mexico. The number of species in the New and Old World may be seen at a glance in the following tabular statement:

	Old World.	New World.	Total.
Starchy Plants (*amylacea*) ...	192	45	237
Oil Plants (*oleosa*)	49	45	94
Sugar Plants (*saccharina*) ...	52	29	81
Acidulous Plants (*acidula*) ...	151	62	213
Saline Plants (*salina*)	122	23	145
	566	204	770

The richness of these lines in food plants may have determined the routes which the races of men adopted in their early migrations—into Europe at least—though what laws govern the growth of these useful plants we do not at present know. But in botanical geography, as the reader will have already learned, there is much which does not appear on the surface, and in trying to explain many intricate phenomena, we must take into consideration changes in the world's history compared with which those recorded by the chroniclers are barely worth noting. Much is, nevertheless, far from clear. But when the vastness of the subject is seen, and the known weighed against what is as yet unsolved, the student has a right to hope for much from the future of a department of physical geography which, to use the language of Schleiden—less applicable now than forty years ago, but still far from inappropriate—is young and "burdened with all the faults of youth, overflowing with the fulness of life, certain of a fair and powerful manhood, but still disorderly and obscure, gathering much at present unintelligible for use in riper years, and as yet dreaming more than thinking."

* Hehn: "The Wanderings of Plants and Animals from their First Home" (1885); Unger, *United States Patent Office Report*, 1859, pp. 299–362.

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